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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

RED ROCK RIVER BASIN
LIMA DAM
LIMA, MONTANA
MT-905

PLEASE RETURN

PREPARED FOR:

HONORABLE THOMAS L. JUDGE

GOVERNOR, STATE OF MONTANA

WATER USERS IRRIGATION COMPANY
(OWNER AND OPERATOR)

PREPARED BY:

MORRISON - MAIERLE, INC.

CONSULTING ENGINEERS

JUNE, 1980

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LIMA DAM

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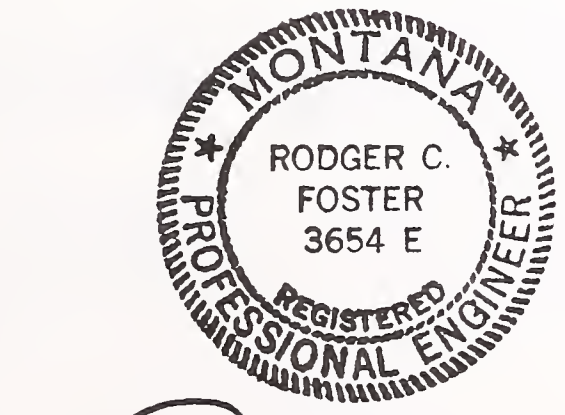
MT-905



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LIST OF CORRESPONDENCE

Water Users Irrigation Company - October 22, 1979.
Montana Department of Natural Resources and Conservation - November 26, 1979.
Department of the Army - January 22, 1980.

LIMA DAM

EXECUTIVE SUMMARY

A technical inspection team from Morrison-Maierle, Inc., accompanied by representatives from the Montana Department of Natural Resources and Conservation and the Water Users Irrigation Company, inspected the Lima Dam on 23 August 1978 under the authority of Public Law 92-367. The dam was revisited on 17 May 1979 by representatives from the Corps of Engineers, Bureau of Reclamation and the same organizations involved in the initial inspection. The Water Users Irrigation Company owns and operates Lima Dam which is located on the Red Rock River in Beaverhead County, approximately 12 miles upstream from Lima, Montana. The project is located near the headwaters of the longest water course in the United States, commonly referred to as the Missouri-Mississippi Rivers.

This report is based on visual inspection, a review of records and design drawings, and interviews with previous inspecting engineers and the resident dam tender. Procedures used in this report are accepted methodologies of other public and private agencies engaged in this field as well as those established in the "Recommended Guidelines for Safety Inspection of Dams", U.S. Army Corps of Engineers.

FINDINGS AND EVALUATION

Lima Dam is a 54-foot high earthfill structure which is capable of impounding 84,050 acre-feet of water at maximum operating pool, elevation 6,582.7 feet M.S.L., and 133,000 acre-feet at top of dam, elevation 6,588.3 feet above M.S.L. Inspection criteria classifies this dam as large in size and because of the potential for loss of life and for extensive property damage resulting from a dam failure, the downstream hazard potential is high (Category 1). Inspection criteria requires such projects to safely handle a full Probable Maximum Flood (PMF). The PMF is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions reasonably possible in the watershed. The PMF was assumed to occur in April or May as a result of rainfall from a 24-hour storm and snowmelt runoff. For the purpose of this inspection, only a partial PMF was considered with runoff from the lower 60 percent of the basin being used. This represents that area below Red Rock Lakes, and was used because of the difficulty in routing a full PMF through these upstream lakes. The partial PMF had a flood volume of 262,000 acre-feet. This value is less than what could be expected from a full PMF.

Lima Reservoir was assumed to be at elevation 6,577.3 feet (spillway crest) with flashboards removed from the spillway and both

outlet tunnels fully open when the partial PMF began. Because of inadequate discharge and/or storage capacity, the reservoir would rise to the top of dam (elevation 6,588.3 feet) in about 15 hours, adding 77,770 acre-feet of surcharge storage to the 55,230 acre-feet of normal storage at spillway crest. At the time of overtopping, the total discharge would have increased to 5150 cfs (about 3200 cfs through the outlets and 1950 cfs over the spillway). Using this combination of discharge and surcharge storage, the project would handle only 35 per cent of the partial PMF volume before overtopping. The PMF routing was made assuming the outlets could safely operate under a full discharge capability. In reality, the ability of the outlets to safely function at maximum discharge capability (which causes pressure flow conditions in the tunnels) is questionable. However, a new routing which limits outlet capacity to prevent pressure flow would not significantly alter the finding that the dam is overtopped at about 35 percent of the partial PMF. Overtopping would occur at an even lesser percent of PMF volume determined for the full drainage basin.

Because of the nature of the dam embankment material, rapid failure of the structure would result from any overtopping. Failure would cause severe downstream flooding, property destruction, and the potential for loss of life as the surge traveled through the valley. The effect on the downstream Clark Canyon Dam and Reservoir is beyond the scope of this report.

The embankment itself has no instrumentation or records on material or foundation. Guidelines require dams such as Lima to have on file stability analyses attesting to the dam's integrity; this is lacking.

Given present limited discharge capability and reservoir storage capacity, Lima Dam does not meet inspection guidelines and is unsafe. Urgent action is called for in gaining additional storage and/or outflow capacity while studies are under way to safely resolve the situation.

RECOMMENDATIONS

Report findings require that the following actions be taken immediately:

1. Retain a qualified engineer to develop a reservoir operation plan to minimize risk of dam failure. This plan must incorporate preparation of an outlet gate operating plan to insure that tunnel flows do not exceed 8.5 feet in depth for any pool elevation.

2. Prepare, implement and periodically test an emergency warning plan to alert downstream interests in event of imminent dam overtopping or structural distress.

3. Provide expedient protection around and downstream from spillway exit to minimize potential for damage should spillway use be required. Remove all stoplogs from spillway.

4. Initiate a plan to, and drain the reservoir. Retain a qualified engineer(s) to investigate and inspect the entire outlet structure and foundation in detail. At the time of dewatering:

a. Provide air venting to the area immediately downstream from the outlet gates to minimize cavitation potential.

b. Accomplish selective surface repair of both outlet tunnels to minimize potential for cavitation. This repair would consist of the repair of larger areas of obviously bad concrete, and the smoothing of large areas having abrupt surface irregularities in excess of approximately one-half inch.

c. If detailed tunnel inspection and investigation reveal that conditions exist which would indicate an unacceptably high risk of imminent tunnel failure with continued operation, accomplish necessary expedient repairs to alleviate such risk prior to allowing the project to refill.

5. Provide a standby motor in the outlet control shed to insure that a capability exists to operate gates by power if the primary motor should not function.

The aformentioned interim measures will not make the project safe but will reduce the risk of failure while the following actions are being accomplished:

1. Retain qualified engineers to (a) determine the full PMF based on the entire drainage area, (b) determine embankment stability for static and seismic loading conditions based on the analysis of the data collected from testing of samples from borings and the installation, monitoring, and evaluation of piezometers, and (c) design adequate spillway and outlet works which, in conjunction with storage, will enable the project to safely handle the PMF. Modify the project in accordance with the formentioned analyses. Outlet design must include provision for emergency closure, air venting and energy dissipation. Replacing the existing outlet with a complete new structure may be advisable in lieu of modifying the existing structure.

2. Prepare and implement a formal written operating and maintenance plan. This plan must include a schedule for periodic inspection at least once every 5 years by qualified engineers with experience in earth dam design and construction.

Prior to implementing any report recommendations the owner is urged to coordinate with the Montana Department of Natural Resources and Conservation.

MORRISON-MAIERLE, INC.

RODGER C. FOSTER
Professional Engineer

RCF/sk

PERTINENT DATA

LIMA DAM - MT-905

LOCATION	Township 13 South, Range 6 West, Section 32 Latitude 44°394', Longitude 112°22.1' Beaverhead County, Montana	
WATERSHED	Red Rock River	
OWNER/OPERATOR	Water Users Irrigation Company (WUIC)	
PURPOSE	Irrigation, recreation and flood control	
YEAR CONSTRUCTED	1890, 1909, 1934	
RECENT INSPECTIONS	17 May 1979 and 23 August 1978, by Morrison-Maierle, Inc., annually (1972-77) by Mr. Bill Morton, P.E., 20 September 1972 by Montana Department of Natural Resources and Conservation	
HAZARD CLASSIFICATION	-HIGH-	
DAM	Type	Earthfill
	Height (feet above D/S toe)	54
	Crest elevation (feet)	6588.3 MSL
	Crest length (feet)	455
	Crest width (feet)	25
	Downstream slope (V to H)	1:2
	Upstream slope (V to H)	1:3
	Volume of fill (cubic yds.)	75,000 approx.
SPILLWAY	Type	Concrete Chute
	Control Section Dimen.	(2) 8½x10-foot openings
	Capacity (cfs)	1950 @ elev. 6588.3
	Crest elevation	6577.3
OUTLET WORKS	Type	Rect. Concrete Tunnel
	Dimensions	(2) ea. 5 ft. wide x 10 ft. high
	Length	109 ft. u/s of gates 160 ft. d/s of gates
	Control	(2) Slide gates 5ft. wide x 10ft. high
	Max. capacity (cfs)	3200 @ elev. 6588.3
	Est. Safe Operating capacity (cfs)	1000 per tunnel
	Invert elevation at gates	6541.8

PERTINENT DATA - Continued

RESERVOIR	Length of max. pool (miles)	15
	Max. reservoir level experienced (ft. msl, date)	6582.88, 13 May '52
	Surface area (acres)	6400 @ elev. 6582.7
	Max. contents @ top of dam (ac-ft)	133,000, @ elev. 6588.3
	Max. operating pool (ac-ft)	84,050, @ elev. 6582.7
	Contents @ spillway crest w/flashboards (ac-ft)	75,180, @ elev. 6581.3
	Contents @ spillway crest w/o flashboards (ac-ft)	55,230, @ elev. 6577.3
	Contents @ time of inspection (ac-ft) August 23, 1978	30,125, @ elev. 6570.1
	May 17, 1979	65,400, @ elev. 6579.5

KEY ELEVATIONS	WUIC Datum	Mean Sea Level
Top of Dam	51.00	6588.3
Max. operating pool	45.42	6582.7
Top of flashboards	44.00	6581.3
Perm. spillway crest	40.00	6577.3
Outlet tunnel invert @ gates		6541.8
Outlet tunnel invert @ downstream portal		6538.2

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority

This report summarizes the Phase I technical inspection and evaluation of Lima Dam, a non-Federal dam owned by the Water Users Irrigation Company of Lima, Montana. Authorization for the inspection is contained in the National Dam Inspection Act, Public Law 92-367, dated 8 August 1972. Nothing contained in this act and no action or failure to act under this act shall be construed (1) to create any liability in the United States or its officers or employees for the recovery of damages caused by such action or failure to act; or (2) to relieve an owner or operator of a dam of the legal duties, obligations or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection was to identify and evaluate existing conditions that may threaten the integrity of the Lima Dam, thereby creating potentially hazardous conditions for downstream areas and to bring these conditions to the attention of proper authorities and the owner.

1.1.3 Inspection

This report, prepared by Morrison-Maierle, Inc., Helena, Montana, is based on visual inspection of the project, a review of records and design drawings, and interviews with a longtime inspection engineer and the resident dam tender. Procedures used during the 23 August 1978 and 17 May 1979 inspections were those established in the Corps of Engineers Guidelines (U.S. Department of Army, 1975). Personnel who formed the technical inspection team on 23 August 1978 were the following:

T. Michael Watson, P.E. - Chief Water Resources Engineer
(Acting Water Project Manager)

Mike Kaczmarek, Chief Geologist/Soils

Philip Porrini, Water Resources Engineer

David Barnett, Structural Engineer

Others present during the inspection included:

Glen McDonald, Montana Department of Natural Resources and Conservation

Rick Burger, Montana Department of Natural Resources and Conservation

Harold Smith, Montana Department of Natural Resources and Conservation

D. J. Doyle, Water Users Irrigation Company

Jerry Welborn, Water Users Irrigation Company

Don Welborn, Water Users Irrigation Company

Byron Martinell, Water Users Irrigation Company

Allen Martinell, Water Users Irrigation Company

Joe Roe, Water Users Irrigation Company

Vern Stanford, Water Users Irrigation Company

Leonard Starks, Dam Tender Water Users Irrigation Company

Those present for the 17 May 1979 inspection were:

Philip Porrini, Morrison-Maierle, Inc.

Jim Lencioni, Corps of Engineers, Seattle District

Ken Graybeal, Corps of Engineers, Seattle District

Mike Nelson, Corps of Engineers, Seattle District

Bob Jones, Bureau of Reclamation (Denver)

Howard Gunderson, Bureau of Reclamation (Billings)

Dick Kennedy, East Bench Irrigation District (Dillon)

Glen McDonald, Montana Department of Natural Resources and Conservation

Robert Clark, Montana Department of Natural Resources and Conservation

David Moss, Water Users Irrigation Company

Leonard Starks, Water Users Irrigation Company

Allen Martinell, Water Users Irrigation Company

1.2 DESCRIPTION OF PROJECT

1.2.1 General

The earthfilled Lima Dam is located in Section 32, Township 13 South, Range 6 West on the Red Rock River in Beaverhead County, Montana (Plate 3). Originally constructed in the early 1890's, the present Lima Dam has undergone significant structural changes in the past and is now 54 feet high and stores 84,050 acre-feet at elevation 6582.7 feet (maximum normal operating pool). The drainage basin above Lima Reservoir includes the unregulated Red Rock Lakes and two small reservoirs on upstream tributary streams that are included in the National Dam Inventory and are identified as: Fish Creek Lake MT - 831, and Widgeon Reservoir MT - 647. The Lima Dam is designated as MT - 905.

The Water Users Irrigation Company (WUIC) owns and operates the dam, which supplies irrigation water to users between Lima and Twin Bridges. The area served by this project is one of the earliest irrigated portions of Montana dating back to 1864. Besides the benefits of providing a reliable source of irrigation water, the reservoir is a recreational area and provides limited flood control. Downstream land- use is primarily irrigated agriculture and livestock production with several of the ranch dwellings located close to the river. The town of Lima (population 351) is located 12 miles downstream from the dam and is the largest town in the Red Rock Valley. Clark Canyon Dam, located approximately 37 miles downstream from the Lima Dam, is owned and operated by the Bureau of Reclamation (Plate 1).

1.2.2 Regional Geology

Lima Dam is located in the Rocky Mountains physiographic province of southwestern Montana. Rugged mountain ranges flanking high intermontane valleys in a basin and range fault-block system characterize the region. The mountain ranges are strongly faulted and folded and exhibit surficial deposits and land forms molded by at least two periods of alpine glaciation. Bedrocks exposed in the mountains vary in age from Precambrian to Tertiary and include metamorphic granite, quartzite, limestone, shale and volcanics.

The intermontane valleys are commonly bounded by normal faults and appear to be downdropped structural blocks. Many major faults in the region show displacement of alluvial fan and glacial deposits.

The intermontane valleys are deep basins that are filled with thousands of feet of Tertiary sedimentary rocks. The Tertiary rocks range from consolidated to semiconsolidated and consist mostly of lacustrine silt stone and silty sandstone interbedded with lesser amounts of fluvial channel conglomerates and a few freshwater limestone beds. The Tertiary rocks are gently folded and a few faults have been identified in the Tertiary basin fills.

Younger deposits overlying the Tertiary basin fill include glacial till and outwash; ice-contact deposits of silt, sand and gravel; old alluvial fill sand and gravel; coalesced alluvial fans along valley margins; and young alluvium, colluvium, landslide and earthflow desposits.

1.2.3 Seismicity

Lima Dam is located in seismic probability Zone 3. The seismic probabilities used herein divide the United States into four seismic risk zones based on the record of the severity of ground shaking and the reasonable expectancy of earthquake damage. Seismic probability or risk in Zone 3 indicates that major destructive earthquakes may occur. Zone 3 corresponds to a potential intensity of VIII and higher on the Modified Mercalli intensity scale of 1931.

Lima Dam and Reservoir are within five miles of a major high angle normal fault which separates the Centennial Valley from the Centennial Mountains. The fault is at least 40 miles long and displacement along the fault may exceed several thousand feet. A similar fault extends in a northwesterly direction from southwest of the town of Lima to the north end of the Tendoy Range and separates the Tendoy Range from the Red Rocks (Lima) Valley. The Centennial fault displays a prominent scarp offsetting alluvial fans and other deposits in the western 15 miles of the fault near Lima Dam. Similar scarps are evident on the southern end of the Red Rocks fault. The east end of the Centennial fault trend becomes indistinct less than 10 miles from the faults that were reactivated in the 1959 Hebgen Lake earthquake.

Most strong earthquakes in Montana have occurred in the western third of the State. Earthquakes in the basin and range fault-block province have exceeded a magnitude of 6 on the Richter scale a number of times and have reached intensities of VIII on the Modified Mercalli scale. The Hebgen Lake earthquake of 17 August 1959 was a 7.1 magnitude earthquake with an intensity of X. Approximately 579,000 square miles were affected by noticeable tremors.

Seismic activity in the Lima Dam vicinity is high and local residents report repeated tremors from small earthquakes (Whitkind, 1975). U.S. Department of Commerce earthquake data indicate that more than 150 earthquakes were recorded in the Lima Dam area between

1960 and 1969. Whitkind (1975) reports oral communication with D.L. Schleicher of the U.S. Geologic Survey in 1973 in which Schleicher reveals that epicenters for the 1960-69 earthquake data concentrate in the Centennial Valley parallel to and north of the northward dipping Centennial fault.

1.2.4 Site Geology

Geologic field investigation at the damsite was limited to observation of the abutments and foundation area. An inspection of the reservoir area was conducted from the air and revealed no unusual geologic features pertinent to dam safety such as foundation faults, landslides, buried channels or other geologic hazards.

The bedrock at the damsite consists of thick beds of Tertiary conglomerate. The conglomerate is quartzose and rich in Belt-type quartzite rocks and is probably the Divide quartzite conglomerate unit of the Beaverhead Formation of Paleocene and Cretaceous age (Ryder and Scholten, 1973). The conglomerate is light to medium gray, has little internal bedding, and consists of pebble gravel ranging in size from less than 1-inch pebbles to boulder gravel exceeding 12 inches in mean dimension set in a matrix of calcareously cemented conglomeratic sand.

The conglomerate beds range from 10 to 12 feet thick and are separated by up to 6-inch thick partings of laminated calcareous siltstone and claystone. The conglomerate forms prominent cliffs and ledges, has blocky splitting properties, and requires from one to several hammer blows to break. The mapping unit designated "Ts" on Plate 10 includes, but is not limited to, the Tertiary conglomerate.

The massive conglomerate bedrock is overlain by Quaternary aged sand and gravel deposits in the local vicinity of the damsite. Two distincly different sand and gravel deposits were observed during the field inspection.

The older deposit supports an eroded but prominent terrace surface approximately 100 feet higher in elevation than the right abutment of Lima Dam. The material is poorly sorted and crudely stratified and appears to represent a remnant of a former continuous cover of fluvially deposited sands and gravels of probable Pleistocene age.

The Pleistocene sand and gravel contains about 5 percent of 10- to 12-inch cobbles, is silty and is dense and compact in place. The unusually high relative density of the material may indicate the preconsolidation effects of at least 100 feet of overburden prior to erosion and downcutting by the Red Rock River. The dense Pleistocene sand and gravel is nonplastic to slightly plastic. Relative density

of the apparently preconsolidated material in outcrops at the level of the dam is estimated to be in the range of 70 to 90 percent.

The younger deposit is present as alluvium in the Red Rock River floodplain and riverbed; is probably Holocene aged; consists of unconsolidated fluvial deposits of silt, sand and gravel containing many cobbles and boulders; and is loose and has a low relative density compared to the Pleistocene sand and gravel. The Holocene sand and gravel is most likely derived from the Pleistocene sand and gravel by reworking and is presumed to consist predominantly of gravelly soils. No distinction is made between the Pleistocene and Holocene sand and gravel deposits on Plate 10 which includes both units in the "Qal" mapping unit.

1.2.5 Description of Dam and Appurtenances

The earthfill dam rises approximately 54 feet above the river bed and extends 455 feet between abutments. The crest of the dam serves as a roadway and is 25 feet wide. The slope of the upstream face of the dam is 1 vertical on 3 horizontal (1V on 3H) and is covered by well-rounded cobbles and boulders generally 12 inches or more in size (Photo 8). The downstream face is no steeper than IV on 2H and is irregular where the embankment from the original dam protrudes as a bench along portions of the present backslope. The downstream face is covered with silty sandy gravel with numerous cobble. Twin rectangular outlet tunnels, each 5 feet wide by 10 feet high, through the earthfill portion of the dam handle the routine discharge requirements of the project. The downstream tunnels (below the control gate) date from the 1909 reconstruction of the Lima Dam, and the inlet portion of the tunnels was built in 1934 when the dam height was raised 10 feet. Rectangular slide gates operated by electric controls in the gatehouse, as shown in Photos 9 and 10, regulate flows through these tunnels. The spillway, a 2-bay, 20-foot wide chute located in the south (left) abutment of the dam, was built in 1934. The permanent spillway crest elevation is 6577.3 feet to which 4 feet of flashboards can be added. The spillway chute is approximately 265 feet in length and drops 43 vertical feet.

1.2.6 Design and Construction History

The need for irrigation water during summer months in the Centennial Valley resulted in the construction of a low dam at the present Lima Dam site in 1890. Little is known about the original construction because no records were kept. Longtime residents agree that no cutoff wall or core was established under the dam and that very little if any surface preparation was made prior to construction (Blindauer, 1939). The dam failed in 1894 (Historical Photos A and B).

Another dam was constructed at the same site in 1908 under the technical supervision of a local engineer, Mr. George Melten (Historical Photo C). The reconstruction was completed in 1909 and salvaged what was left of the original 1890 dam. This 40-foot high earthfill structure developed serious leakage and assorted piping erosion of the embankment fill adjacent to the outlet works and, in May 1933, the reservoir was drained to prevent a complete dam failure resulting from piping around the outlet tunnels. Rehabilitation was completed in 1934, including extension of the outlet tunnel, a new spillway and the addition of 10 feet of height to the previous embankment. There is no record detailing repairs made in the area of failure. There are two design drawings available (Plates 4 and 5) for the present structure which has not been modified during the past 44 years. Correspondence files developed since the rehabilitation work document records of previous inspections. (Fifield, 1939, 1954; Brittain, 1940)

1.2.7 Physiography, Climatology and Hydrology

The 570 square mile drainage area above the Lima Dam begins at the Continental Divide near Yellowstone Park in southwestern Montana. The major axis of the roughly elliptical basin is 40 miles long. The Red Rock River flows westerly through the center of the basin, which is referred to as the Centennial Valley and collects tributary streams from the Gravelly Range and the Centennial Mountains. Mount Jefferson (elevation 10,196) at the eastern drainage boundary is the highest point in the basin and is above timberline. The crest of Lima Dam is at an elevation of 6588.3 feet. Approximately 17 percent of the drainage is forested, 4 percent is water covered, and the remaining area is grasslands. Numerous lakes and swamps present in the Centennial Valley upstream of the Lima Reservoir affect the routing of peak flood events. Most notable of these lakes are the Upper and Lower Red Rock Lakes. The Red Rock River below the Lima Dam flows 55 river-miles to the Clark Canyon Dam from which flows the Beaverhead River. The Red Rock River is at the start of the country's longest watercourse, the Red Rock - Beaverhead - Jefferson - Missouri - Mississippi Rivers.

Climate in the Centennial Valley is a picture of extremes and typical of a continental type. Summer temperatures often exceed 80°F by day and drop to 40°F by night. Winter temperatures often remain below freezing for long periods and sub-zero readings are common. Table 1 shows average daily temperatures for the two weather station locations shown on Plate 2.

Table 1. Average Daily Temperatures
(U.S. Department of Commerce, 1977)

Station	(Number)	Years of Record	January (°F)	July (°F)
Lima	(5030)	43	16.5	62.1
Lakeview	(4820)	33	8.2	58.7

Average annual precipitation ranges from 11 inches at Lima to 40 inches on the northern slopes of the Centennial Mountains. May and June are the wettest months of the year, accounting for 35 percent of the annual precipitation. The remainder is nearly equally distributed over the remaining 10 months. Snow may fall in the higher elevations almost anytime of the year, but accumulates from early fall through the following spring. The National Weather Service (NWS) and the Soil Conservation Service (SCS) maintain temperature/precipitation and snow survey stations, respectively, in and around the drainage basin (Plate 2).

The U.S. Geological Survey (USGS) is currently operating stream gages at two locations on the Red Rock River below the dam and has collected 32 years of record from a discontinued third station above the dam. Continuous daily records of reservoir storage elevation are recorded by the WUIC and published by the USGS. Station #60125, with a drainage basin of 570 square miles, has partial records of flow below the dam dating back to 1911. Station #60145, with a drainage basin of 1548 square miles, has minimal records prior to 1974 and is currently in operation downstream from station #60125. USGS station #60110, with a drainage basin of 323 square miles, was in operation above the reservoir until 1967.

The mean annual runoff at station #60125 exceeds 100,000 acre-feet per year with most discharge occurring in the three-month period between May and July. Peak events commonly occur from May to mid-June. A maximum recorded discharge of 2,500 cubic feet per second (cfs) was estimated by the dam tender during emergency releases in 1933.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 SPILLWAY DESIGN FLOOD

Based on the reservoir storage and hazard classifications, the recommended spillway design flood (SDF) in the inspection guidelines is the Probable Maximum Flood (PMF).

2.2 HYDRAULICS AND STRUCTURES

2.2.1 Spillway

The chute spillway is located in the left abutment of the dam and consists of two 8½ X 10-foot openings on a broad flat crest (Photos 2, 3, 5 and 7). At these twin openings, timber flashboards are used to raise the level of the reservoir as much as four feet, thereby increasing storage from 55,230 at spillway crest (elevation 6577.3) to 75,180 acre-feet (maximum operating pool is yet another 1.4 feet higher at 84,050 acre-feet). Controls shown in Photo 6 are used for removal of flashboards although flashboard removal during their overtopping is not operationally feasible. Just downstream of the flashboard controls and above the twin openings is a bridge for vehicular access to the south side of the reservoir. The bridge is supported by the walls of the spillway openings. Within the width of this bridge structure is the control point for spillway discharges. At the control actual flow depths undergo a transition through critical depth and flow classification changes from subcritical to supercritical. The development of a rating curve through this control required calaculations of critical depth and water surface elevations to the reservoir. Subsequently, the water surface profile computer program HEC-2 (U.S. Department of the Army, 1976) was used to establish the spillway discharge versus reservoir elevation curve shown in Plate 7. The resulting spillway capacity at elevation 6588.3 (top of dam) is 1950 cfs.

Downstream of the control section, the bottom width of the spillway chute, reduces from 20 to 10 feet and the slope steepens from .075 to .420 ft./ft. The channel depth in the chute is six feet and the chute walls have 1:1½ backslopes. The 264-foot long chute terminates in a stilling basin approximately 30 X 35 X 7-feet in size that does not contain structural energy dissipating devices. The condition of the concrete in the spillway walls and floor is generally good. There are a few small cracks and spalls in the walls, especially where the 1:1½ backslope chute walls join the floor slabs. Plate 5 indicates spillway chute design details.

Although during maximum spillway discharge, water depth in the trapezodial shaped chute is below wall heights, energy dissipation is inadequate.

2.2.2 Outlet

The concrete outlet tunnels through the earth embankment were constructed in two stages. The twin 5 X 10-foot tunnels, originally built in 1909, are 269 feet long. At that time, the outlet controls were at the upstream end of the tunnel along the reservoir edge. In 1933 a piping failure occurred around the tunnels and in 1934 the dam was raised ten feet and 100 feet of twin 5 X 10-foot inlet tunnel was added to the reservoir side of the outlet controls. Plate 4 suggests that the bottom of this added tunnel section is to be found in bedrock while the remainder of the tunnel (roof, walls, etc.) appears to be in the embankment material. Additional design information for the 1909 and 1934 outlet tunnels is limited.

Flow through the outlet tunnels is regulated by slide gates which are electrically operated. Manual operation is also possible. The controls for the gates are located on the crest of the dam in a gatehouse above a wet well (Photos 9 and 10). During normal operation, the gates are opened to identical amounts and total discharge is less than 500 cfs. During full open gate conditions the tunnel would flow full and under pressure with the discharges controlled by entrance configuration. Due to unknowns involved in the design, construction and foundation, pressure flow in the tunnel may be hazardous. Limiting gate openings to insure that the outlet tunnels do not flow in excess of 85 percent of full depth is advisable. Calculation of the discharge capacity for each tunnel indicates an estimated maximum discharge of 1000 cfs is possible with the gate controlling flow at 85 percent of full depth in the tunnels. Rating curves for the outlet tunnels are shown in Plate 8.

The slide gates measure 5 feet wide by 10 feet high and are of unknown design and manufacture. The gates have functioned well since their installation in 1909 and the seepage past the gate seals observed during the 23 August 1978 inspection does not constitute a safety hazard or operational deficiency. The scaling observed on the downstream side of the gates does not pose a safety hazard. The controls for the north slide gate had a tendency to bind when the gates were opened at the conclusion of the inspection. The binding indicates stress either along the gate seals or in the control mechanism that should be watched and corrected if the condition becomes worse. There is no record of any work on these gates since 1933. The assessment of their condition is based only on observations made of the downstream side of the gate. A review of the operating records indicates that the slide gates have been only fully opened once since 1909 (during the 1933 failure).

There is no emergency closure provision for the operation of the gates, nor is there any way to perform gate maintenance without taking extreme action such as draining the reservoir. Access to the gates is either by way of the outlet tunnel or the wet tower, both of which are normally in an underwater state.

The outlet tunnels upstream from the gates were not observed during the inspection because they were underwater. It is not known if trashracks exist at the inlet portal. Inspection of the outlet tunnels downstream from the gates revealed numerous patches which had been made in previous years. Irregularities along the tunnel floor have been observed since 1968 but are essentially due to construction practices at the time of construction and concrete spalling rather than due to extensive cracking and settlement. There are no air vents downstream of the gates to satisfy the air requirements at high reservoir levels and critical gate openings. Conditions appear to be normal for wear and deterioration following 70 years of service and no definite areas of cavitation damage exist. This may only indicate that critical combinations of gate openings and reservoir levels have never been experienced. Seepage enters both tunnels through the ceiling approximately 20 feet downstream of the operating slide gates. The 1933 construction drawings show that weep holes were drilled at these locations. The intermediate wall between the left and right tunnels was substantially deteriorated at the downstream end of the tunnels until October 1978 when repairs were made to several parts of the outlet structure (Photos 11 and 13).

A State of Montana dam safety inspection in 1972 (Montana Department of Natural Resources and Conservation, 1972) revealed that the concrete floor at the discharge end of the outlet tunnels was undermined most likely due to inadequate energy dissipation. The State inspectors also reported considerable seepage flowing from the sand and gravel foundation under the outlet tunnels. In October 1978, the undermined area and the downstream discharge basin in the channel was filled with boulders and cemented in place with concrete (Photo 14).

Channel conditions downstream of the outlet structure need improvement. The outlet basin is reportedly plagued by erosion and undermining. About 1,000 feet downstream from the dam, a sharp crested weir and recording device is operated by the USGS and measures all flows from the dam. The channel appears stable downstream of the weir.

2.2.2.1 Left (South) Outlet Tunnel

Two holes are present in the ceiling of the left outlet tunnel, a 7-inch and a 2-inch diameter hole located approximately 22 and 27 feet respectively downstream from the gate (Photo 15 depicts the

7-inch hole). Seepage through these holes continues at the rate of constant trickle as it has historically been reported. Two construction joints in this tunnel are offset up to approximately 4 inches due to differential displacement and/or concrete deterioration. One joint is about 35 feet from the gate; the other is at the discharge end of the tunnel. Approximately 50 feet from the gate, along the intersection of the left wall and the roof, there is a 5-foot long seepage area. A hole in the lower left wall, approximately 100 feet downstream of the gate, is 6 inches in diameter behind which a void between the tunnel liner and foundation exists. The maximum depth of this void was measured to be 15 inches from the inside face of the tunnel, thus assuming a tunnel wall surface of 10 inches, the void extends 5 inches into the foundation. By extending ones forearm into the hole, the foundation material felt hard and is surmised to be rock. Observation of seepage flow from this void did not show evidence of the transportation of fines.

2.2.2.2 Right (North) Outlet Tunnel

There is a 2-inch diameter hole 20 feet from the gate in the right tunnel ceiling. Clear water was flowing freely through this hole. About 10 feet from the downstream end of the tunnel there is a 5-inch diameter hole through the wall that separates the tunnels (Photo 16). Settlement of the tunnel floor at several locations has been reported by others. The 17 May 1979 inspection revealed several depressed areas having the appearance of settlement, but close inspection showed these are apparently caused by irregular construction joints and subsequent concrete spalling. No significant floor settlement was observed.

2.2.3 Freeboard

Lima Reservoir is 15 miles long and has an east-west orientation. With the dam at the western extreme of the reservoir there is less than one mile of effective fetch. Prevailing winds in the area are from the west. Therefore, wind generated waves are directed away from the dam and have minimal effect on the embankment. At normal pool there is seven feet to the dam crest which is more than adequate to prevent overtopping. During the PMF the dam is overtopped and no freeboard is available.

2.3 HYDROLOGY

2.3.1 Reservoir Stage and Spillway Discharge

Spillway discharges at the Lima Dam are regulated to some degree by the flashboard arrangement at the crest. Four feet of elevation above the permanent spillway crest elevation may be used for additional irrigation storage. Flashboards are left in the year-round unless there is a forecast for above average runoff in

the spring. Daily records of reservoir elevation are compiled by the dam tender but do not provide sufficient detail to identify periods of spillway use. The USGS gaging station below the dam provides total discharge information. However, it is not known exactly when and how much of this flow discharges through the spillway.

2.3.2 Probable Maximum Flood

The probable maximum flood (PMF) calculated for this report is not based on the total Lima Dam drainage. It is a partial PMF based on the drainage area below the Red Rock Lakes (approximately 60 percent of the total basin) and the total stream length of Long Creek, a Red Rock River tributary (Plate 2). This procedure was recommended by the Corps of Engineers, Seattle District, to eliminate the uncertainty of routing through the Red Rock Lakes. A PMF calculation for the total Lima Dam drainage would produce a larger peak and volume than the partial PMF presented here, but would require a detailed study of the Red Rock Lakes.

To calculate the partial PMF, a 24 hour April-May storm was selected as the most critical event for the Lima drainage. This event, known as the probable maximum precipitation (PMP), was determined by the procedures outlined in the Weather Bureau Technical Paper No. 38 (U.S. Department of Commerce, 1960). The storm was scheduled in 30-minute increments to provide a critical time sequence. The PMP total for 24 hours is 14.0 inches. Because of the high elevation of the Lima Dam drainage and the probability that a 24-hour PMP storm would occur in April or May, it was assumed that the ground would be frozen. Therefore, no losses would occur between precipitation and runoff. A unit hydrograph was developed by procedures outlined in the Design of Small Dams (U.S. Department of Interior, 1977). The unit hydrograph and the PMP were used as input for the HEC-1 Flood Hydrograph computer program (U.S. Department of the Army, 1978). Base flow was assumed to equal 200 cfs.

2.3.3 Routing

Several conditions were assumed in routing the partial PMF through the Lima Reservoir: 1) pool elevation at the permanent spillway crest (6577.3); 2) all flashboards permanently removed; and 3) both outlets fully open. These assumptions were made to determine the percentage of the partial PMF at which the dam would overtop assuming the most optimistic conditions. In reality, operation of the outlets with full gate openings is considered hazardous and definitely not recommended. However, limiting outlet capacity to prevent the occurrence of pressure flow conditions in the outlet tunnel will not significantly alter the percent of PMF causing overtopping.

The stage-storage curve for Lima Dam (Plate 6) was extrapolated for elevations above maximum operating pool based on USGS topographic maps and the conic method. The results indicate a storage reserve between permanent spillway crest elevation (55,230 acre-feet @ elevation 6577.3) and the dam crest (approximately 133,000 acre-feet @ elevation 6588.3) of approximately 77,770 acre-feet. Routing studies using the storage between spillway crest and the top of dam and with outlet gates fully open show that Lima Dam would handle 35 percent of the partial PMF, based on a total flood volume of 262,000 acre-feet. A 50 percent partial PMF overtops the dam by almost 4 feet and a full partial PMF overtops the dam by almost 14 feet.

2.4 GEOTECHNICAL EVALUATION

The geotechnical evaluation presented here is based on facts observed at Lima Dam during the 23 August 1978 inspection, correspondence regarding seepage experienced in 1933, construction drawings for the 1934 rehabilitation work, and photographs of the structure made in 1890 and sometime after 1909. Review of previous dam safety inspection records and other correspondence reveals that the present earthfill embankment includes portions of two earlier embankments. No data is available regarding zoning, stratification, material strengths or location of the piezometric surface in the embankment or foundation material.

2.4.1 Dam Embankment

The Lima Dam embankment is a composite fill containing portions of embankments built in 1890, 1909 and 1934. In its present configuration, the dam embankment has a crest length of approximately 455 feet and the width of the crest ranges between 20 and 30 feet. The upstream face backslope, exposed with the reservoir storage 18 feet below the crest, is a 36 percent slope or roughly a 1V on 2.8H slope. The backslope below the water surface is not known. The upstream face is surfaced with riprap consisting predominantly of 10- to 12-inch quartzite cobbles which show no evidence of deterioration or displacement. The downstream face of the dam is irregular due to the presence of intermediate benches where fill from the older 1909 structure protrudes from the face and where an access road is cut into the face. The downstream face consists of silty sandy gravel with numerous cobbles with a maximum slope of approximately 48 percent or a 1V on 2H slope.

The right abutment of Lima Dam consists of preconsolidated Pleistocene silty sand and gravel deposits. The dense materials stand in near vertical slopes above the right abutment where they are cut by the main road to Lima. There is no evidence of backslope failure in the old cuts. Inspection of the contact between the dam embankment and the right abutment material reveals no evidence of seepage above the embankment toe. A nearly stagnant pond at the toe

in this area has some seepage entering from the dam and abutment. The road cut area and the right abutment appear to be the main borrow area from which fill for much of the dam embankment was derived. The left abutment of Lima Dam consists of Tertiary conglomerate bedrock which strikes generaly N 50° E and dips 18° to 19° back into the reservoir. Conjugate joints dipping perpendicular to the bedding planes are present on approximately 6-foot centers and exhibit slight slickensides on their surfaces. The degree of induration and cementation of the conglomerate is demonstrated by the joints which cross-cut quartzite and limestone pebbles. Inspection revealed no evidence of seepage or slope failure in this left abutment. The degree of induration and cementation of this rock suggests that it is essentially impermeable.

The 1909 embankment was increased 10 feet in height and the steep upstream face modified to a 1V on 3H slope in 1934 by adding compacted fill. Evidently most of the 1909 fill was retained when the dam was increased in height in 1934. Although previous reports of inspections at this dam agree that no cutoff or core wall was used, records obtained from Mr. Frank A. Hazelbaker, Dillon, Montana, in 1934, of cost and quantities of materials used in construction of the 1890 and 1909 dams include 155 yards of masonry core used in the 1890 dam. The 155 yards of masonry would be sufficient material to construct a core wall 400 feet long, 1 foot thick and 10 feet high. However, there is no record of the final applicaton of the materials itemized on the contractor's list.

The soils comprising the 1934 embankment were placed in lifts and roller compacted with concrete rollers that are still present at the dam. There is no record of whether or not the older 1890 and 1909 embankments were roller compacted. The borrow material that comprises the silty sand and gravel fill used for all three embankment stages appears to have been the Pleistocene alluvial deposits obtained from the right abutment. Inspection of the upstream and downstream faces did not reveal any areas of slope instability, settlement or misalignment in the fill. Similarly, no areas of face seepage were evident at the time of inspection. The downstream face is fairly heavily covered with brush.

Except for minor seepage into a near-stagnant pond at the right abutment, the only areas of embankment seepage noted during the inspection were in the rectangular concrete outlet tunnels. Seepage was entering the ceiling of the right outlet tube through a 2-inch diameter hole about 20 feet downstream from the control gates. The hole is in the location of a concrete crib shown on the old drawings above the outlet tunnels and may be a weep hole which has been enlarged by deterioration of the concrete. The hole has been observed by previous inspectors since at least 1933 and does not appear to present a safety hazard in terms of structural stability.

A second area of inflowing seepage water discharge was observed in the left wall of the left outlet tunnel approximately 40 to 50 feet downstream from the control gate. A hole approximately 4 to 6 inches in size is present in the concrete wall at its juncture with the floor slab. Considerable amounts of water were observed flowing through the hole into the outlet tunnel. During the inspection of the hole on 17 May 1979, it was observed that the concrete wall was approximately 10 inches thick behind which a void extended 5 inches. The foundation material felt hard and is surmised to be conglomerate bedrock. A piece of conglomerate bedrock was taken from inside the north wall of the right tunnel yielding evidence of the foundation material.

Seepage into the tunnel through the walls is not abnormally high, but does represent an area of concern. This seepage condition has long been noted and is on record with the State. The emergency drawdown of the reservoir in 1933 to prevent a piping failure along the outlet tunnel continues to promote some uncertainties as to the origin and extent of seepage and pressure. Little information exists as to the repair and reconstruction of the Lima Dam in 1934, therefore, the possibility of interconnected voids behind the outlet tunnel walls exists. Information provided by historic photographs and the 22 May 1933 letter and sketch to Mr. George Melten, Design Engineer, (Water Users Irrigation Company, 1933) regarding seepage problems experienced in 1933 relate most of what is available on the pre-1934 Lima Dam. Historic Photo A, dated around 1890, shows an outlet tunnel through solid rock in the left abutment. The rock tunnel was evidently used as an outlet works. The sketch enclosed with the 1933 letter to Mr. George Melten shows an "old rock tunnel" aligned diagonally under the 1909 (approximate date) spillway and the letter relates observation of seepage problems located by entering and inspecting the rock tunnel.

Historic Photo C and the 1933 construction drawings of rehabilitation of the dam show that the 1909 to 1933 open channel spillway was also the outlet for the main control gates. The 1909 spillway was covered by a concrete roof in 1934 and became the outlet tunnels and a new spillway (the present spillway) was constructed at a new elevation and further to the left on the bedrock abutment. These facts suggest that the "old rock tunnel" of the 1933 letter and sketch is the same rock tunnel shown in Historic Photo A.

If the latter surmise is correct, as much as 50 to 100 feet of the outlet tunnels immediately downstream from the main control gates may be founded in conglomerate bedrock. Certainly, the facts indicate that the existing outlet tunnels were definitely subjected to the 1933 seepage problem. The 1933 letter graphically describes the collapse of embankment fill into piping channels along at least 40 feet of the upstream face adjacent to the right side of the outlet works. Piping of embankment fill away from the base of the

embankment along the interface with bedrock was observed through a hole excavated through the embankment to the mouth of the old tunnel. The separate piping paths extended through the embankment, along a cut-off collar, along the spillway (outlet tunnel) wall and along the foundation bedrock interface.

A record does not exist for the repairs made to the area of piping in the embankment, prior to raising the embankment height by 10 feet. The geometry of the present embankment indicates that the additional fill placed on the embankment considerably lengthened the potential seepage path for piping and pore pressures should have reduced accordingly.

2.4.2 Foundation Conditions

The foundation of Lima Dam from the left abutment to at least the right side of the main control gate structure consists of Tertiary conglomerate similar to the rock exposed on the left abutment. Foundation material beneath the remainder of the embankment is unknown but probably consists of alluvial sand and gravel (Quaternary in age) of unknown thickness (Plate 10).

The extent of foundation preparation is unknown but is suspected to be minimal. Inspection revealed seepage issuing from the alluvial gravel at the discharge end of the outlet works. However, no positive distinction between foundation underflow, as opposed to release of bank storage after closing of the headgates, could be made. Photographs taken by Mr. Bill Morton during inspection conducted in recent years positively shows seepage through the alluvial foundation materials beneath the discharge apron of the outlet works.

The current inspections also revealed a pool of nearly stagnant seepage water at the toe of the embankment adjacent to the right abutment. The water level in this pool was 31 feet below the storage level in the reservoir on 23 August 1978. No surface water was flowing from this seep which occupies a low spot that may be a pre-dam alluvial channel or possibly a canal from a previous structure at this site. However, small seeps could be seen discharging into the nearly stagnant seepage water from the dam and right abutment. Reports of seepage from this location are recorded in correspondence as early as 1933.

2.4.3 Stability

A formal stability analysis for the embankment of Lima Dam is not recorded. The minimum data necessary for an embankment stability analysis does not exist. Corps of Engineers guidelines require that stability analyses be on record for all dams in the high downstream hazard category and that the computed safety factor not be

less than 1.5 for the steady seepage condition. Stability analyses for the Lima Dam embankment must take into consideration the presence of the seepage observed at the right abutment. In addition suitable conventional embankment stability analysis for seismic loading conditions must be on file for all dams in seismic probability Zones 3 and 4. Lima Dam is located in Zone 3. The history of seismic activity in Centennial Valley and nearby areas combined with the evidence of geologically recent (if not historically recent) movement along the Centennial fault underscore the importance of the embankment stability analysis for seismic loading conditions.

2.5 PROJECT OPERATION AND MAINTENANCE

2.5.1 Dam

Operation and maintenance of the Lima Dam is accomplished by the WUIC. A dam tender responsible for the daily operation and routine maintenance lives in a house located at the dam. The dam tender, Mr. Leonard Starks, has worked in this capacity since 1954. Personal contact with Mr. Starks and minutes for WUIC annual meetings (Water Users Irrigation Co., 1972-1977) provided valuable information regarding the operation of the dam and prior maintenance activities. Telephone contact between the dam tender, the WUIC and the Bureau of Reclamation at Dillon, is maintained during the irrigation season. Forecasts issued by the SCS and NWS are used by the WUIC to determine if there is a need to alter their operating plan for the filling of the reservoir in the early spring during the runoff season. Normally, all flashboards are left in the spillway structure. However, if SCS and NWS forecasts indicate the possibility of potentially high inflow, as many as four feet of flashboards are removed to reduce the maximum operating pool elevation to 6577.3 feet. Daily records of reservoir levels are kept by the dam tender.

The lowest reservoir storage levels typically occur in the fall. Increases in storage may take place during the winter but the predominant period for filling is in early spring. When the reservoir is full (75,180 acre-feet of storage) excess water is allowed to flow over the spillway. During normal operation, discharge is through the twin outlet tunnels. Flows are regulated by slide gates with electrically operated controls located in the gatehouse on the crest of the dam. Routine maintenance of the controls, and the hoisting mechanism which raises and lowers the 6 X 12 X 48-inch flashboards is performed as needed.

A formally written operating plan has not been prepared. The operating procedures used by the directors of the WUIC and the dam tender are based on many years of pragmatic experience in managing and operating the dam and irrigation project. Interviews with the directors and the dam tender revealed a high degree of familiarity with the capabilities of the project and the necessary decision

making and communication procedures on the part of the personnel responsible for the project.

Annual inspection of the dam since the 1934 reconstruction has been the rule rather than the exception. Numerous reports and correspondence are on file with the Montana Department of Natural Resources and Conservation in Helena, Montana, and the Water Users Irrigation Company in Lima, Montana. Many of the earlier inspections were made by the Montana State Water Conservation Board at the request of the WUIC and more recently have been made by Mr. Bill Morton, P.E., at the request of the WUIC. Minor maintenance items noted on these reports have generally received attention. Major discussion topics such as outlet tunnel relining and spillway reconstruction have been going on since 1939 and still are a source of contention.

2.5.2 Warning System

Continuous monitoring of the project operation is provided by the resident dam tender. Calls to the valley residents, the Lima office of the County Sheriff and the Bureau of Reclamation commonly accompany the start of any significant increases in outlet or spillway releases. The National Weather Service cooperates with local radio and television stations in issuing flash flood watches and warnings based on meteorological data available at offices around the state.

2.6 SAFETY EVALUATION

Detailed study of topography or hydraulics of the area between Lima Dam and Clark Canyon Reservoir was not made. The following discussion is based on an approximation of floods from a ruptured dam (U.S. Department of the Army, 1974). The primary usage of the broad valley floor below Lima Dam is for agriculture and livestock propagation (Photo 1). The town of Lima is located 12 miles downstream from the dam and lies between the elevations of 6220 and 6260 feet. The Red Rock River flows through the valley at Lima at elevation 6210. Downstream of Lima the river flows northwesterly through approximately 25 miles of irrigated agricultural land before entering the Clark Canyon Reservoir. The meandering river flows past three ranches in the reach between the dam and the town of Lima and past an additional six or more ranches before it reaches the Clark Canyon Reservoir.

The same general storm that would cause Lima Reservoir to fill and overtop would cause high runoff in the valley downstream from Lima Dam. This runoff, together with outflow from Lima Dam, would cause flooding conditions prior to an overtopping failure of Lima Dam. Overtopping of Lima Dam would likely produce a deep and wide cut through the earthfill embankment within a matter of a few hours.

This type of failure would create a surge of water traveling downstream from the dam. The surge is estimated to reach Lima within two hours and cause flooding in the northeast part of town. Extensive additional loss of agricultural property would take place between Lima Dam and Clark Canyon Reservoir as a result of dam failure. The residents of the upper valley floor would have the least warning time for evacuation in the event of dam failure and would face the highest risk of loss of life. For the above reasons, Lima Dam is classified unsafe due to its inability to safely handle possible flood inflows. The design and existing conditions in and around the outlet tunnels also present a concern for safe project operation. In addition, failure of Lima Dam could create a domino effect on downstream reservoirs. Of immediate concern would be Clark Canyon Dam, a Bureau of Reclamation project. Because of the widespread nature of the storm that would generate inflows to Lima Reservoir sufficient to cause Lima Dam to overtop, and the possible reservoir regulation in effect at Clark Canyon Dam during such a storm, a detailed analysis is required to determine if Clark Canyon Reservoir could safely handle the additional flood volume if Lima Dam should fail.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

The results of a visual inspection of the structure, review of the records and design drawings, and interviews with a long-time inspecting engineer and the resident dam tender are presented in the following paragraphs.

3.1.1 Classification

The Recommended Guidelines for Safety Inspection of Dams (U.S. Dept. of the Army, 1975) classifies dams according to size and hazard potential. The Lima Dam with a storage capacity of more than 50,000 acre-feet is categorized as large in size. Dam failure would cause extensive economic losses and the potential loss of many lives. Therefore, the hazard potential is classified as high.

3.1.2 Spillway

Combined spillway and optimistic outlet capacity with all flashboards removed and the tunnel gates completely open provides for a discharge of 5150 cfs with reservoir storage level at the crest of the dam. This discharge with available surcharge storage allows the project to safely handle up to 35 percent of the partial PMF. Dam safety inspection guidelines recommend that Lima Dam safely handle a full PMF. Floods in excess of discharge and/or storage capacity will overtop and fail the dam, causing downstream property destruction and potential loss of life as the flood surge travels through the downstream valley.

Structural deficiencies exist at the spillway stilling basin where undermining of the downstream walls and floor exists. Peak spillway discharges could topple these walls. The stilling basin does not provide adequate energy dissipation, causing possible downstream channel erosion. Further channel erosion would endanger the spillway chute and ultimately the embankment.

3.1.3 Outlet

The safe operation of the outlets with gate openings allowing a full flow (pressure) is suspect. In order to insure that the tunnels do not operate under pressure, it is advisable to limit gate opening to provide maximum flow depths of 8.5 feet in the tunnels. The controls in the gatehouse are well maintained. Both gates were opened slightly after the inspection and binding of the right control was noticed. The gates have not been fully opened since 1933. The wet

tower was inspected to the extent possible, but at the inspection time (23 August 1978) the reservoir level was down only 18 feet and therefore, much of the tower was underwater. The 109-foot long tunnel upstream of the gates was also underwater and was not inspected and has never been inspected to our knowledge. Provisions for air venting downstream from the slide gates to minimize cavitation potential do not exist. Facilities for emergency closure of the outlet gates are also lacking. Should the electric motor for gate operation fail, gate operation by hand is possible but would be very time consuming.

Minor amounts of seepage enter the outlet tunnels below the leaking slide gates at various locations. This condition has long been noted in letters and reports on file with the State. In 1933, emergency drawdown of the reservoir took place to minimize a piping failure along the outlet tunnel. No information is available as to the extent of the repairs that followed. A possibility of interconnected voids behind the outlet tunnel walls exists. Recent reports have also indicated that seepage comes from beneath the apron of the outlet structure. Irregular tunnel floor surfaces have been observed since 1968. However, this is apparently due in large part to construction irregularities and concrete spalling rather than extensive cracking and settlement. Erosion downstream from the outlet exit resulting from inadequate energy dissipation structures has received recent attention. Large rocks and concrete were used to riprap an area where undermining was threatening to weaken the outlet apron. Horizontal drains have been installed to collect and relieve seepage pressure beneath the apron. The effectiveness of these drains is not known as no piezometers exist for measuring hydrostatic pressures.

No specific requirements dealing with outlet capacity have been established under dam safety guidelines. Minimum drawdown time from normal maximum operating pool to zero storage would require approximately 30 days with an assumed inflow of 200 cfs and assuming full operational capability of the outlets.

3.1.4 Dam

The dam embankment appears to satisfy general design criteria and no evidence of face seepage problems, settlement, displacement or slope failure are evident. Seepage is occurring through the foundation near the right abutment. However, historic reports indicate no significant changes. The origin and extent of seepage flow and seepage pressure associated with the outlet tunnels is unclear and is of concern. General maintenance of the embankment is good. However, brush growing on the downstream face of the embankment has developed to an objectionable extent and should be removed. No stability analyses are on file for this structure and embankment stability cannot be assessed because of insufficient available data.

3.1.5 Safety Evaluation

Given the project's inability to safely handle possible inflows and the potential downstream effects of this inability, Lima Dam is unsafe. There is concern over the design and physical conditions surrounding the project's outlet tunnels.

3.2 RECOMMENDATIONS

Report findings require that the following actions be taken immediately:

3.2.1 Retain a qualified engineer to develop a reservoir operation plan to minimize risk of dam failure. This plan must incorporate preparation of an outlet gate operating plan to insure that tunnel flows do not exceed 8.5 feet in depth for any pool elevation.

3.2.2 Prepare, implement and periodically test an emergency warning plan to alert downstream interests in the event of imminent dam overtopping or structural distress.

3.2.3 Provide expedient protection around and downstream from the spillway exit to minimize the potential for damage should spillway use be required. Remove all spillway stoplogs.

3.2.4 Initiate a plan for draining and drain the reservoir. Retain a qualified engineer(s) to investigate and inspect the entire outlet structure and foundation in detail. At the time of dewatering:

a. Provide air venting to the area immediately downstream from the outlet gates to minimize cavitation potential.

b. Accomplish selective surface repair of both outlet tunnels to minimize the potential for cavitation. This repair would consist of repair of larger areas of obviously bad concrete, and smoothing of large areas having abrupt surface irregularities in excess of about one-half inch.

c. If detailed tunnel inspection and investigation reveal that conditions do exist which would indicate an unacceptable high risk of imminent tunnel failure with continued operation, accomplish the necessary expedient repairs to alleviate such risk prior to allowing the project to refill.

3.2.5 Provide a standby motor in the outlet control shed to insure that the capability exists to operate the gates by power if the primary motor should not function.

The aformentioned above interim measures will not make the project safe but will reduce the risk of failure while the following actions are being accomplished:

3.2.6 Retain qualified engineers to (a) determine the full PMF based on the entire drainage area, (b) evaluate embankment stability for static and seismic loading conditions based on the analysis of all available and additional data collected from test borings, soil sampling and testing, and the installation, monitoring, and evaluation of piezometers, and (c) design adequate spillway and outlet works which in conjunction with the storage will enable the project to safely handle the PMF. Modify the project as required for stability and safety in accordance with the aforementioned analyses. Outlet design must include the provision for emergency closure, air venting and energy dissipation. Replacing the existing outlet with a completely new structure may be advisable in lieu of modifying the existing structure.

3.2.7 Prepare and implement a formal written operation and maintenance plan. This plan must include a schedule for periodic inspection at least once every 5 years by qualified engineers with experience in earth dam design and construction.

Prior to implementing any report recommendations the owner is urged to coordinate with the Montana Department of Natural Resources and Conservation.

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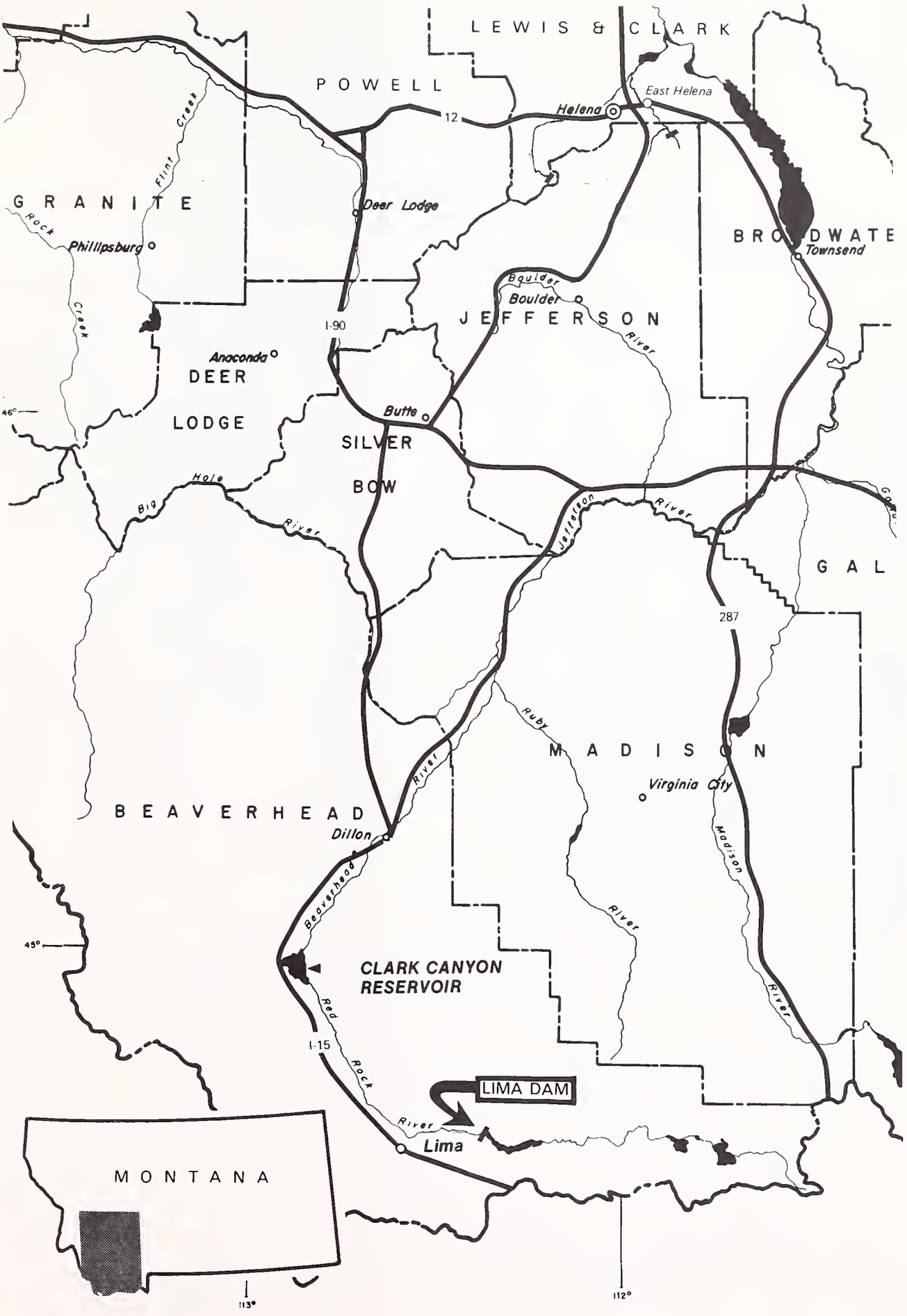


PLATE 1 LIMA DAM VICINITY MAP

LEGEND

Agency	Code	Number	Name	Type	Years of Record
NWS	◓	5030	Lima	Temp/Precip.	43/55
		5811	Monida	Precip.	/24
		4820	Lakeview	Temp/Precip.	33/35
SCS	⊕	11E03	Lakeview Ridge	Snow Survey	30
		11E04	Lakeview Canyon	Snow Survey	30
		11E24	Teepee Creek	Snow Survey	12
		11E32	Sawtell Mountain	Snow Survey	11
		12E06	Notch	Snow Survey	15
		12E07	Divide	Snow Survey	15
USGS	▲	60110	Red Rock River	Stream Gage	31
		60125	Red Rock River	Stream Gage	48

NWS—National Weather Service SCS—Soil Conservation Service

USGS—U. S. Geological Survey

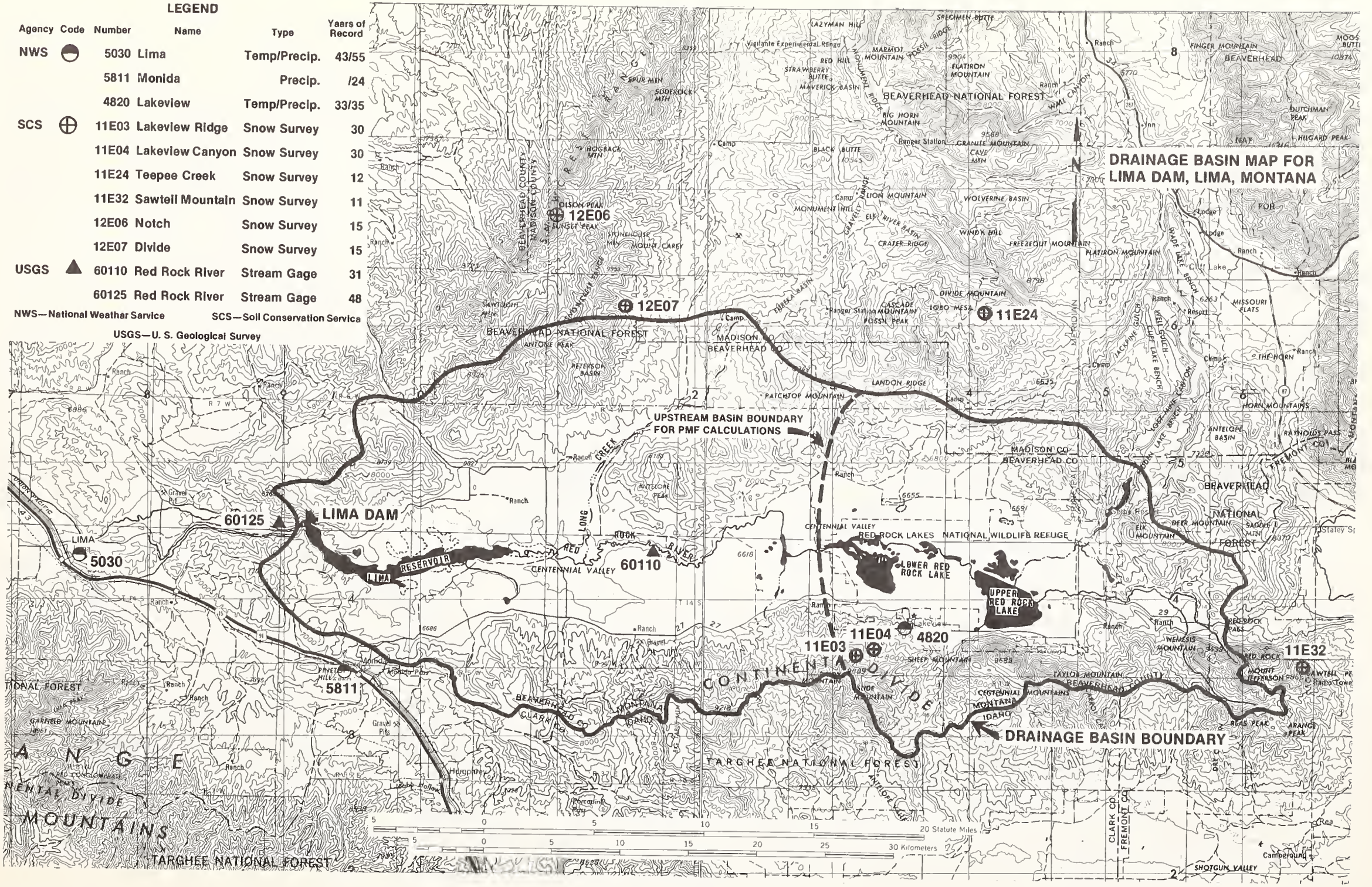


PLATE 2
DRAINAGE BASIN MAP

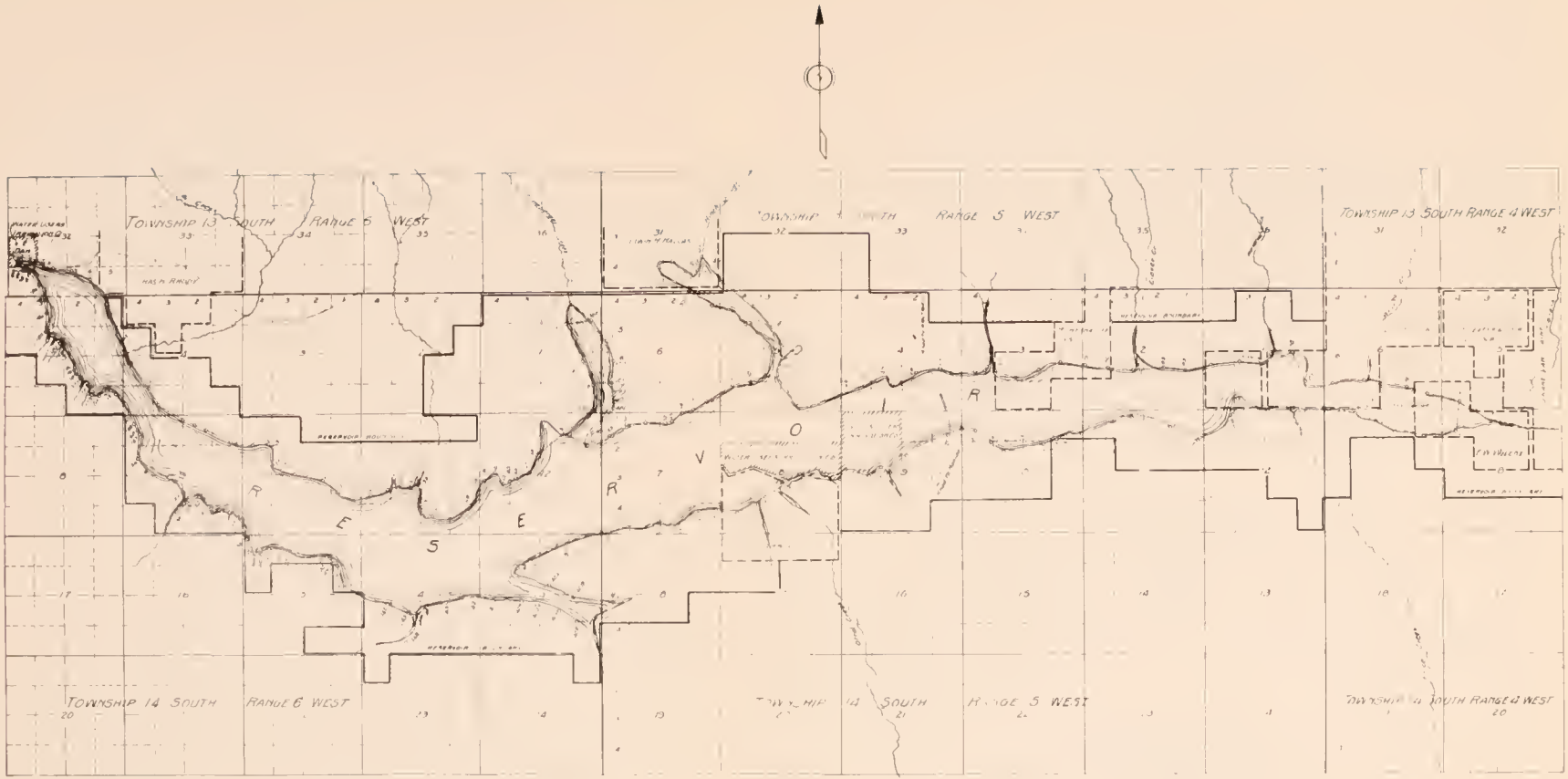
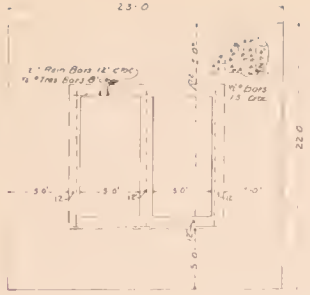
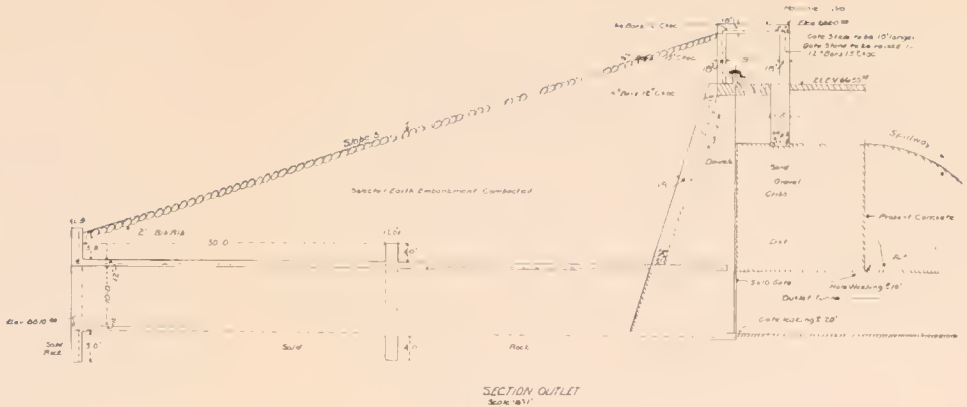
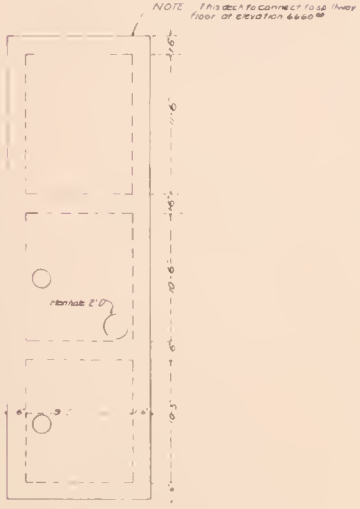
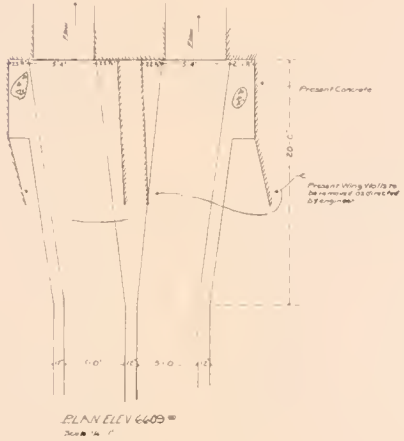

TOWNSHIP 13 SOUTH RANGE 6 WEST
TOWNSHIP 13 SOUTH RANGE 5 WEST
TOWNSHIP 13 SOUTH RANGE 4 WEST
RESERVOIR
TOWNSHIP 14 SOUTH RANGE 6 WEST
TOWNSHIP 14 SOUTH RANGE 5 WEST
TOWNSHIP 14 SOUTH RANGE 4 WEST

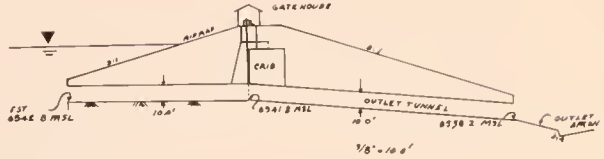
PLATE 3 RESERVOIR











ELEVATIONS ARE AT PROJECT
DATUM AND DO NOT CORRE-
SPOND TO TEXT.
MSL = Project Datum-70.3 ft.
Sheet reduced to 37.5% of original.

OUTLET CONTROL
WATER USERS IRRIGATION COMPANY
DILLON MONTANA JUNE 1953
PANALELBAKER SEC TV HATCHER ENG

PLATE 4 OUTLET CONTROLS

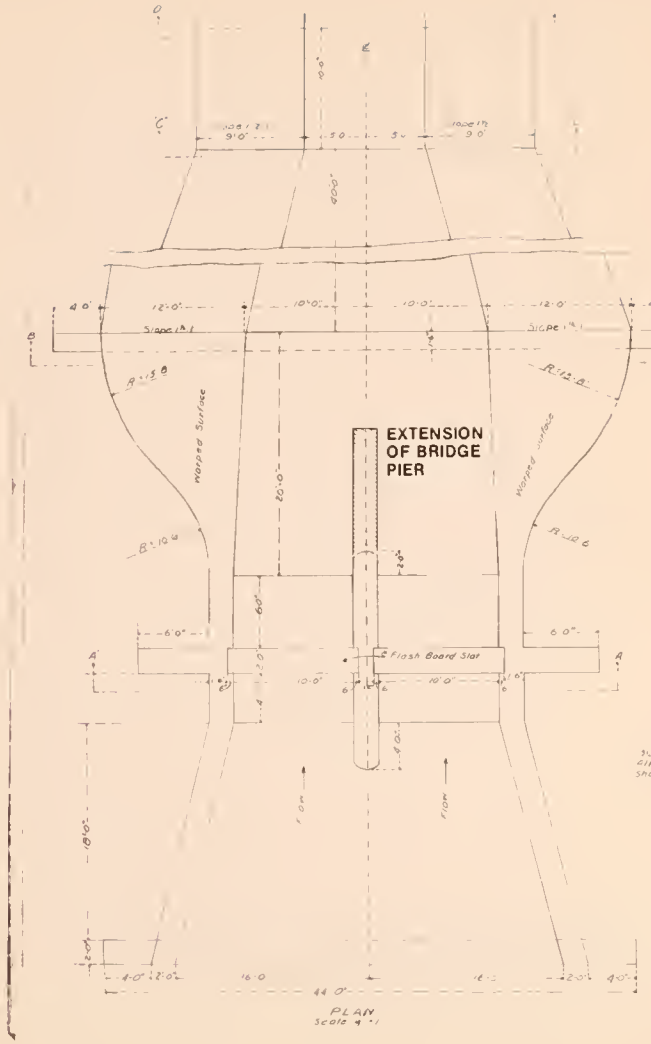
STATION 140

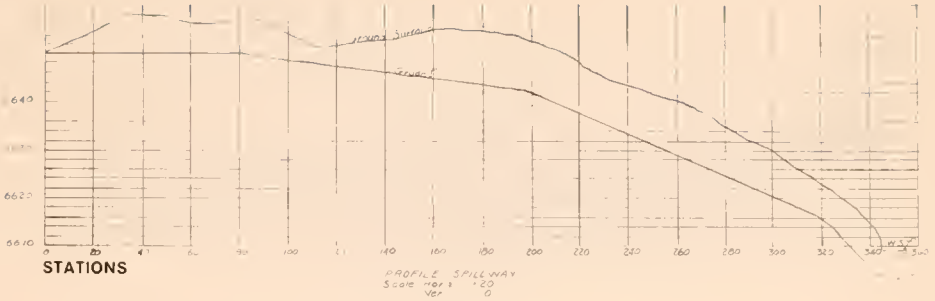
STATION 100

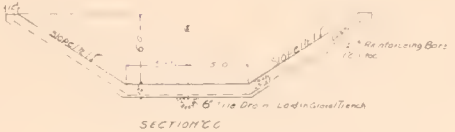
STATION 80

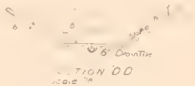
STATION 60

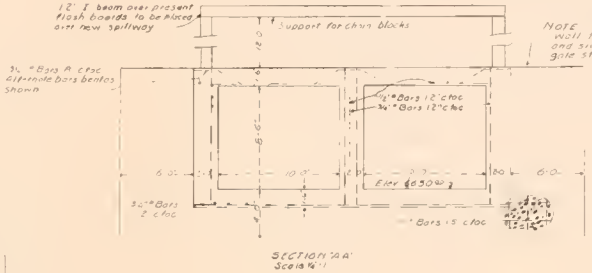
STATION 50











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SPILLWAY

WATER USERS IRRIGATION COMPANY

DILLON MONTANA — JUNE 1933

SHEET NO 2

2-B-81

PLATE 5 SPILLWAY

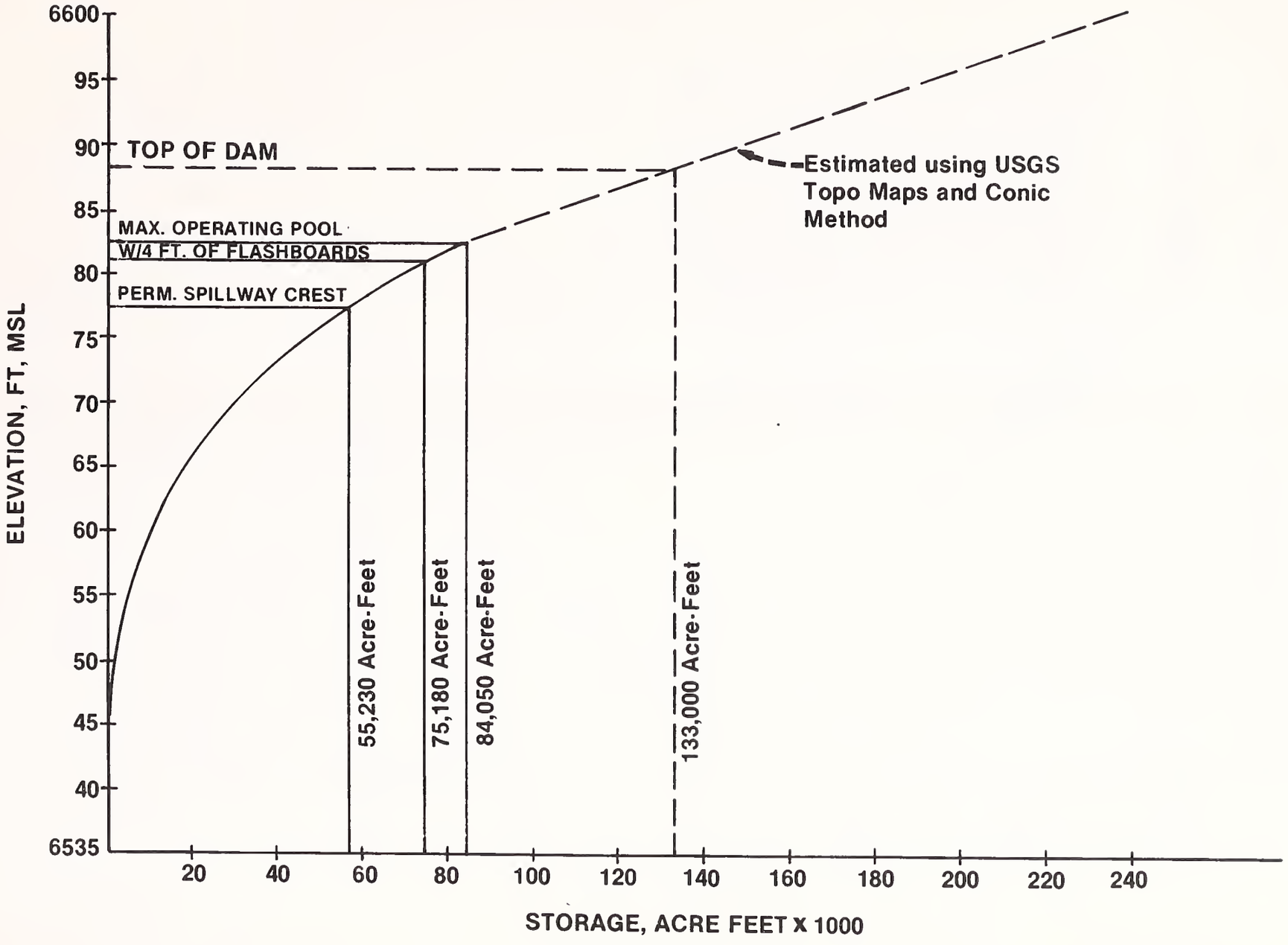


PLATE 6 LIMA DAM STAGE—STORAGE CURVE

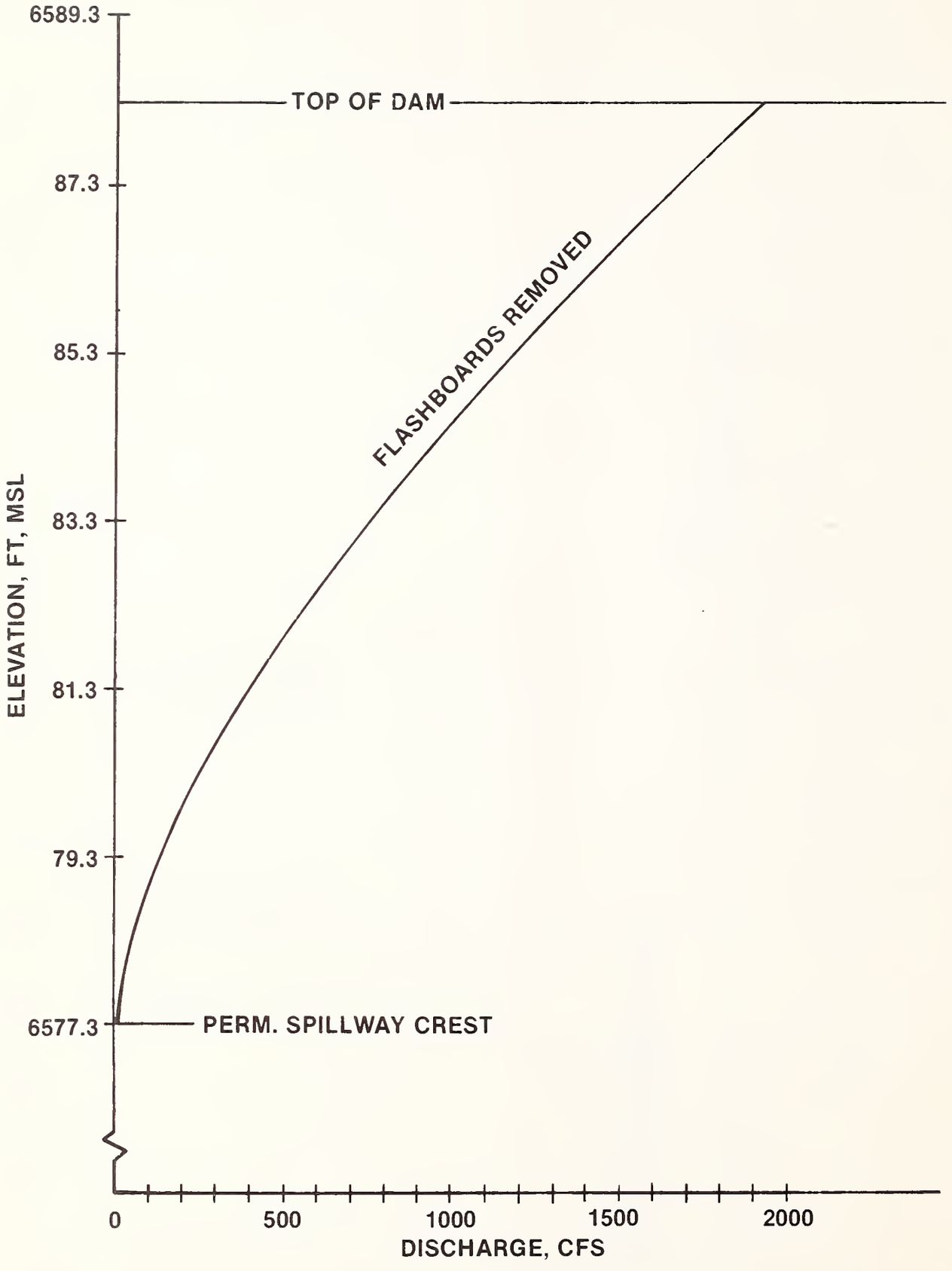


PLATE 7 LIMA DAM SPILLWAY RATING CURVE

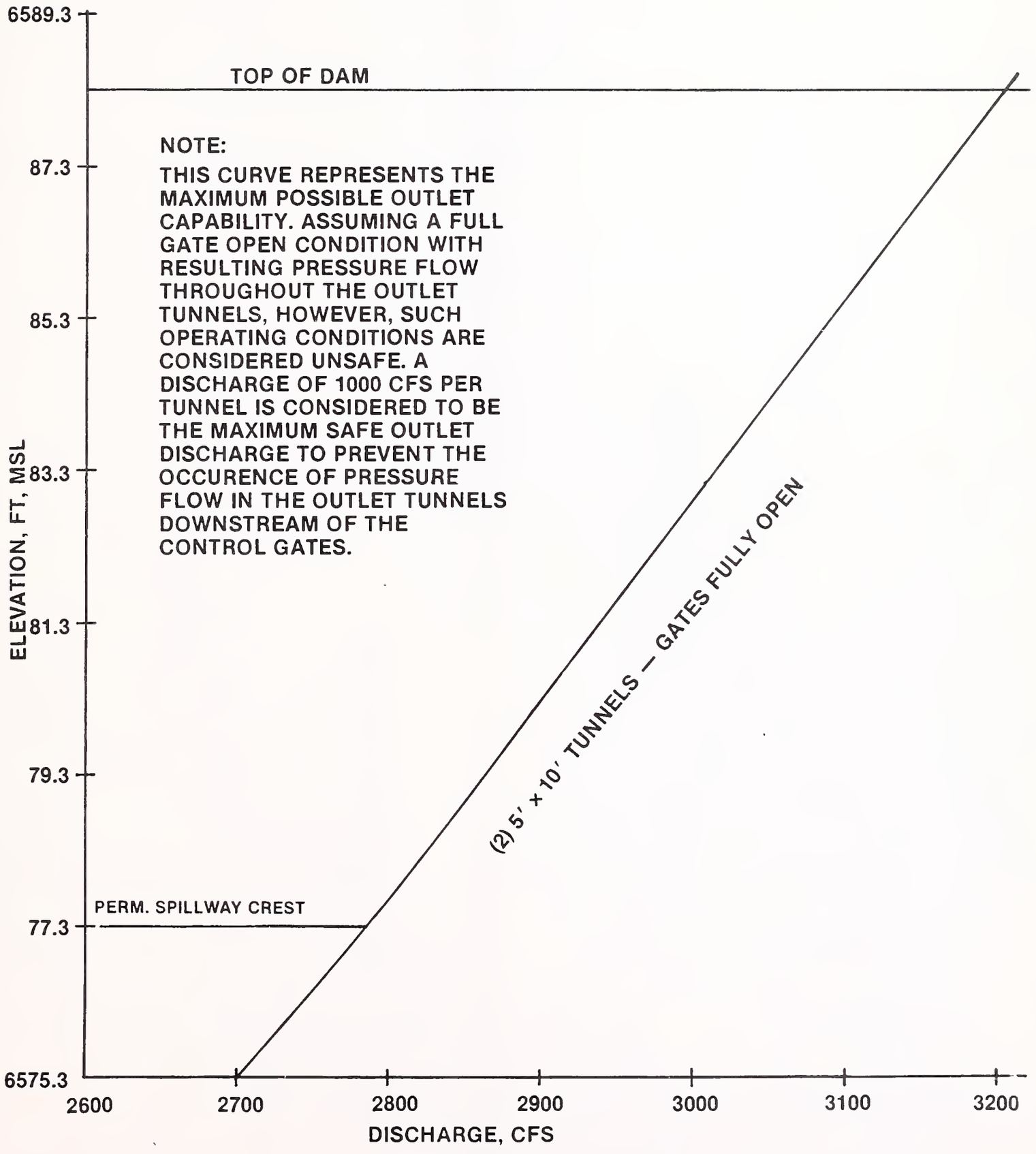
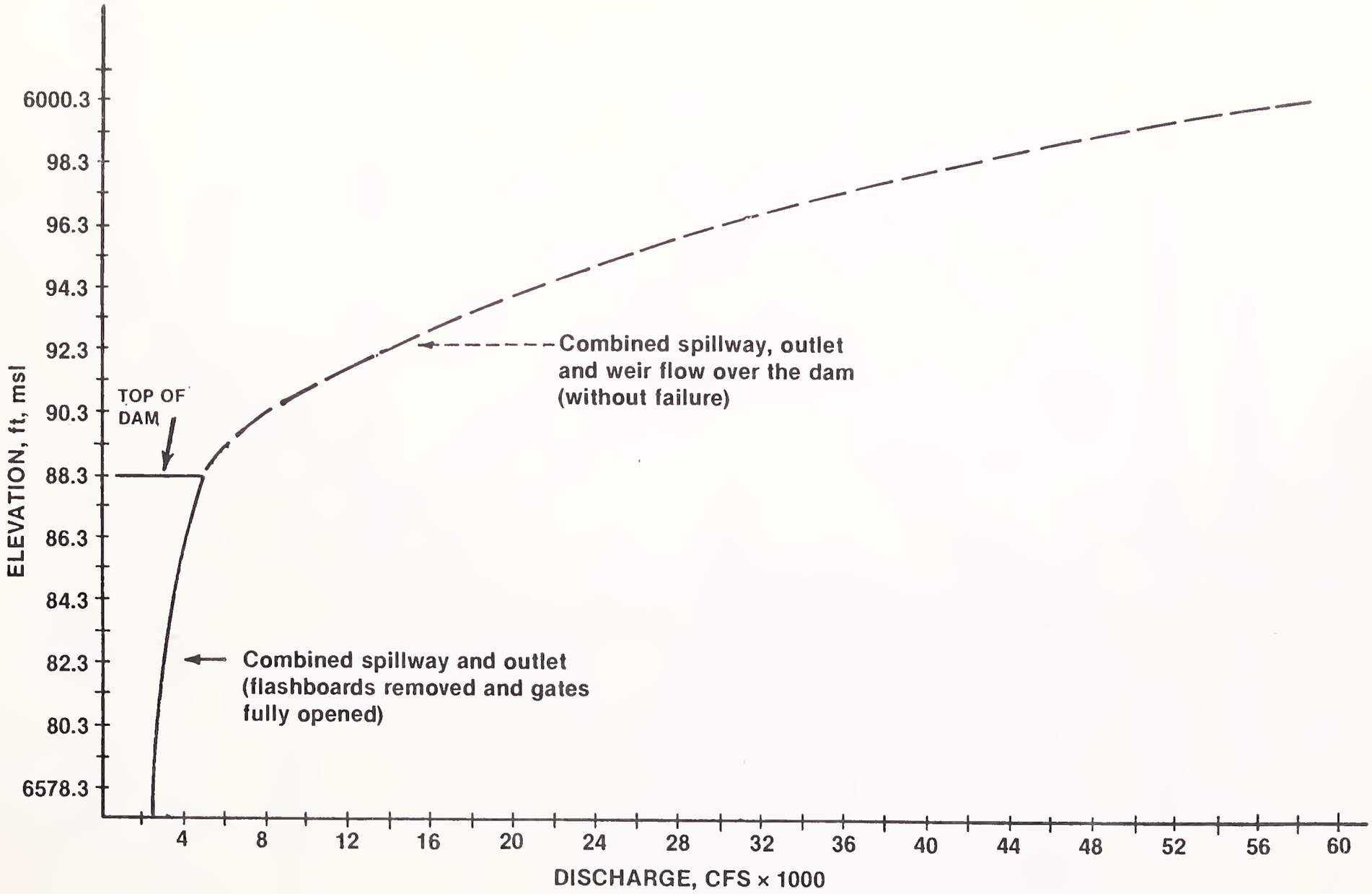

6589.3
TOP OF DAM
NOTE:
THIS CURVE REPRESENTS THE MAXIMUM POSSIBLE OUTLET CAPABILITY. ASSUMING A FULL GATE OPEN CONDITION WITH RESULTING PRESSURE FLOW THROUGHOUT THE OUTLET TUNNELS, HOWEVER, SUCH OPERATING CONDITIONS ARE CONSIDERED UNSAFE. A DISCHARGE OF 1000 CFS PER TUNNEL IS CONSIDERED TO BE THE MAXIMUM SAFE OUTLET DISCHARGE TO PREVENT THE OCCURENCE OF PRESSURE FLOW IN THE OUTLET TUNNELS DOWNSTREAM OF THE CONTROL GATES.
87.3
85.3
83.3
81.3
79.3
(2) 5' x 10' TUNNELS — GATES FULLY OPEN
PERM. SPILLWAY CREST
77.3
6575.3
ELEVATION, FT, MSL
2600
2700
2800
2900
3000
3100
3200
DISCHARGE, CFS

PLATE 8 LIMA DAM OUTLET RATING CURVE

PLATE 9 LIMA DAM STAGE—DISCHARGE CURVE IN OVERTOPPING SITUATION



EXPLANATION:
SEDIMENTARY ROCKS

- Qal ALLUVIAL SEDIMENTS
- Ts TERTIARY ROCKS
- Brx OLDER BEDROCKS
- A A' CROSS SECTION
- EMBANKMENT FILL

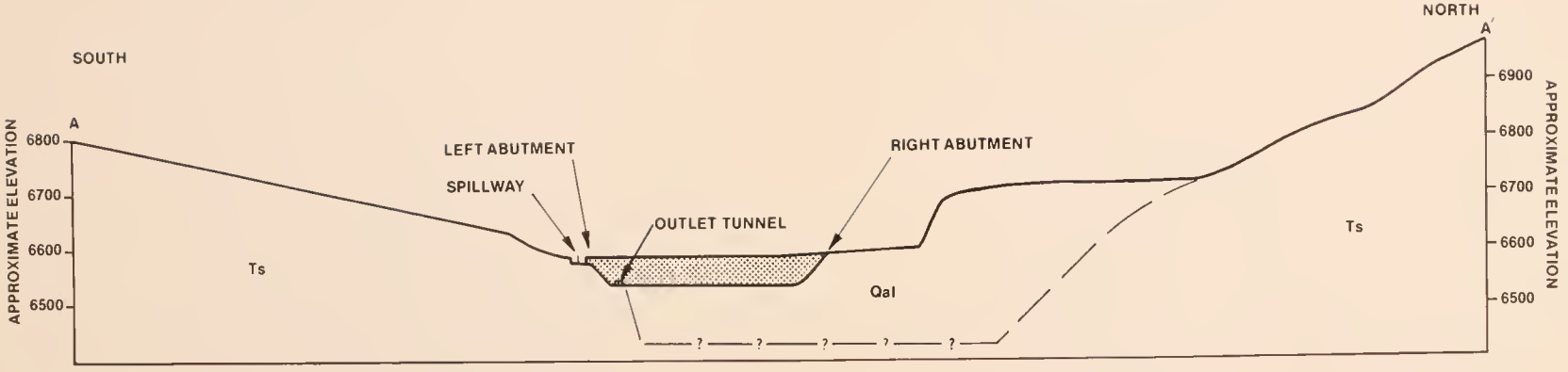


PLATE 10 GEOLOGIC MAP AND CROSS SECTION

Photo 1 AERIAL VIEW OF LIMA DAM AND DOWNSTREAM VALLEY

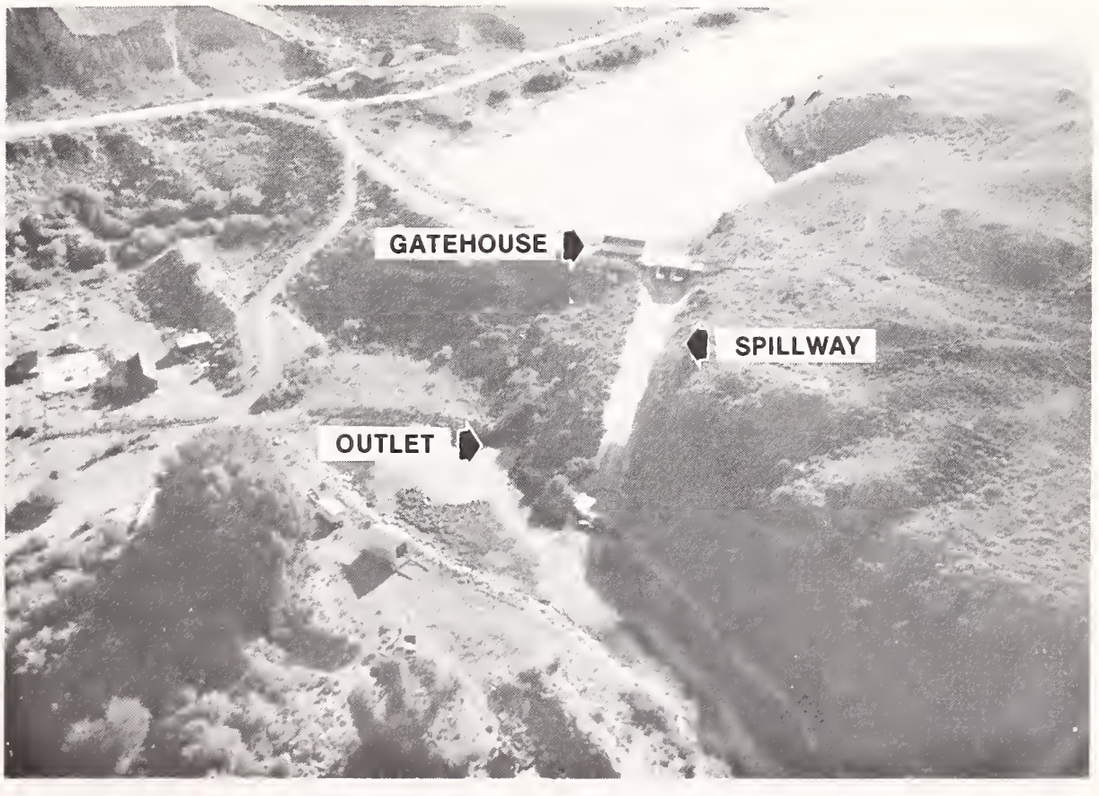


Photo 2 AERIAL VIEW OF LIMA DAM INDICATING GATEHOUSE, SPILLWAY AND OUTLET STRUCTURE LOCATION

INSPECTION PHOTOGRAPHS TAKEN, AUGUST 23, 1978

Photo 3 SPILLWAY CHUTE

Photo 4 OUTLET STRUCTURE

Photo 5 OUTLET AND SPILLWAY STRUCTURES

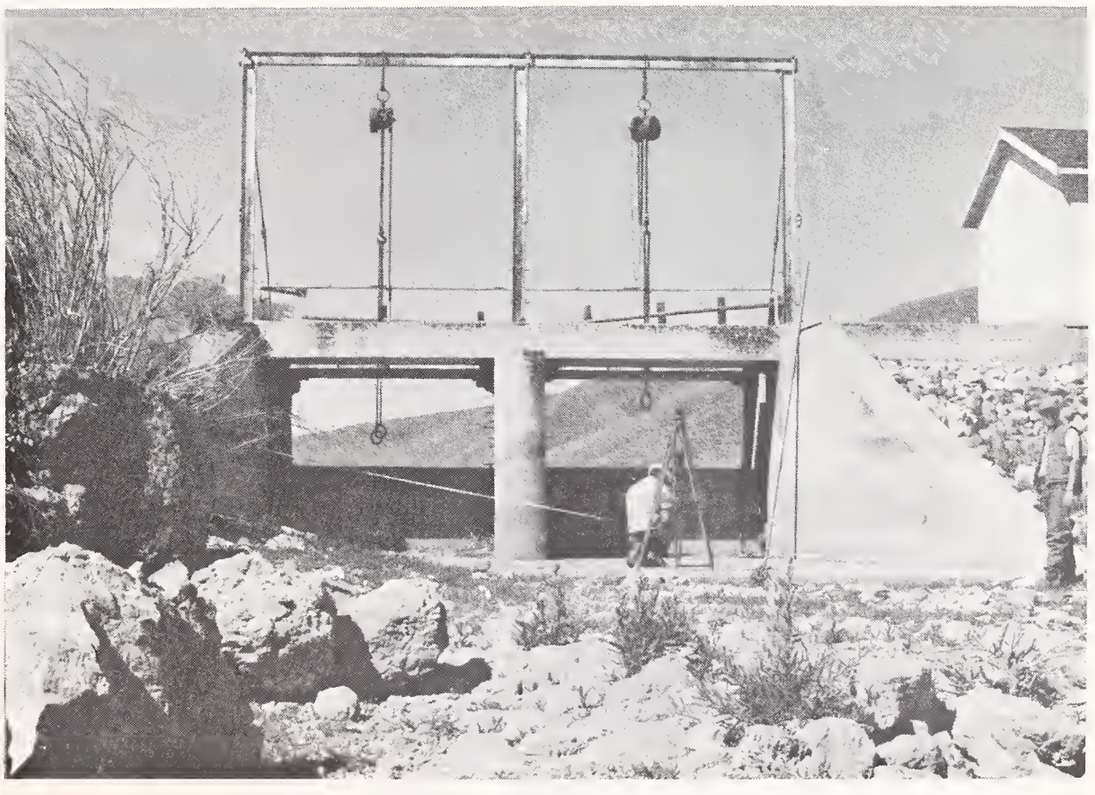


Photo 6 SPILLWAY CREST AND CONTROLS

Photo 7 FLASHBOARD ARRANGEMENT IN SPILLWAY STRUCTURE

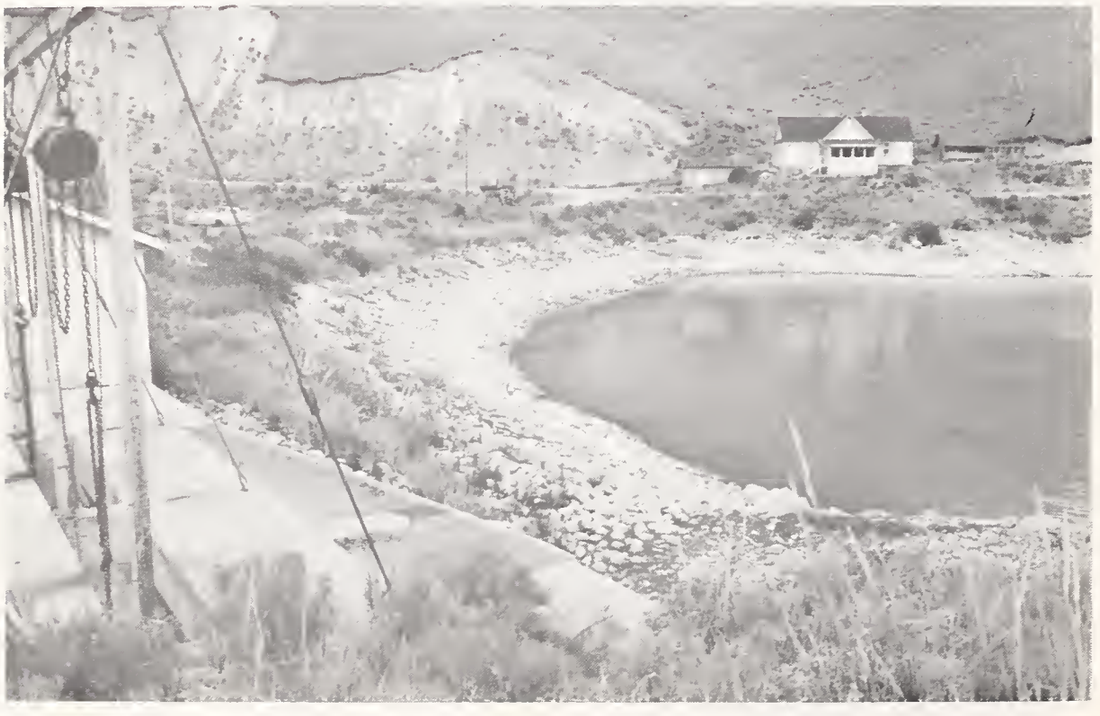


Photo 8 UPSTREAM FACE OF DAM — COBBLESTONE RIPRAP AT 3:1 SLOPE — DAM TENDERS HOME IN BACKGROUND

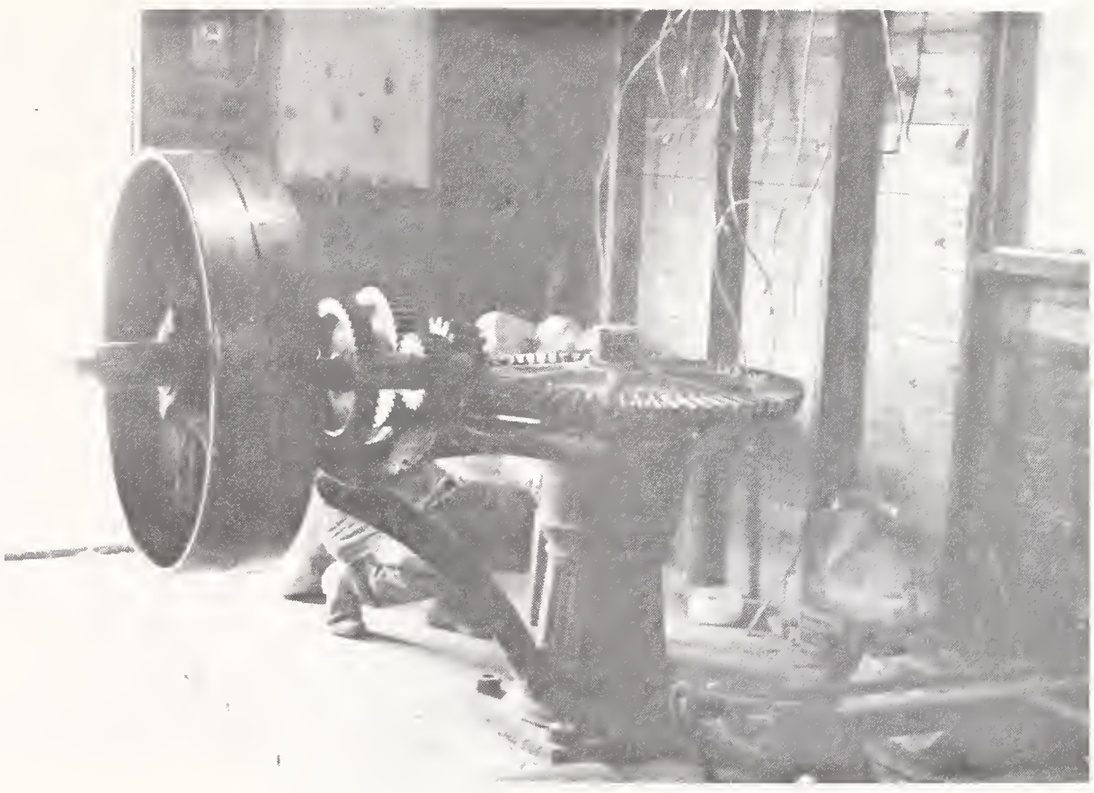


Photo 9 OPERATING CONTROL FOR RIGHT TUNNEL — LARGE WHEEL IS BELT DRIVEN BY ELECTRIC MOTOR

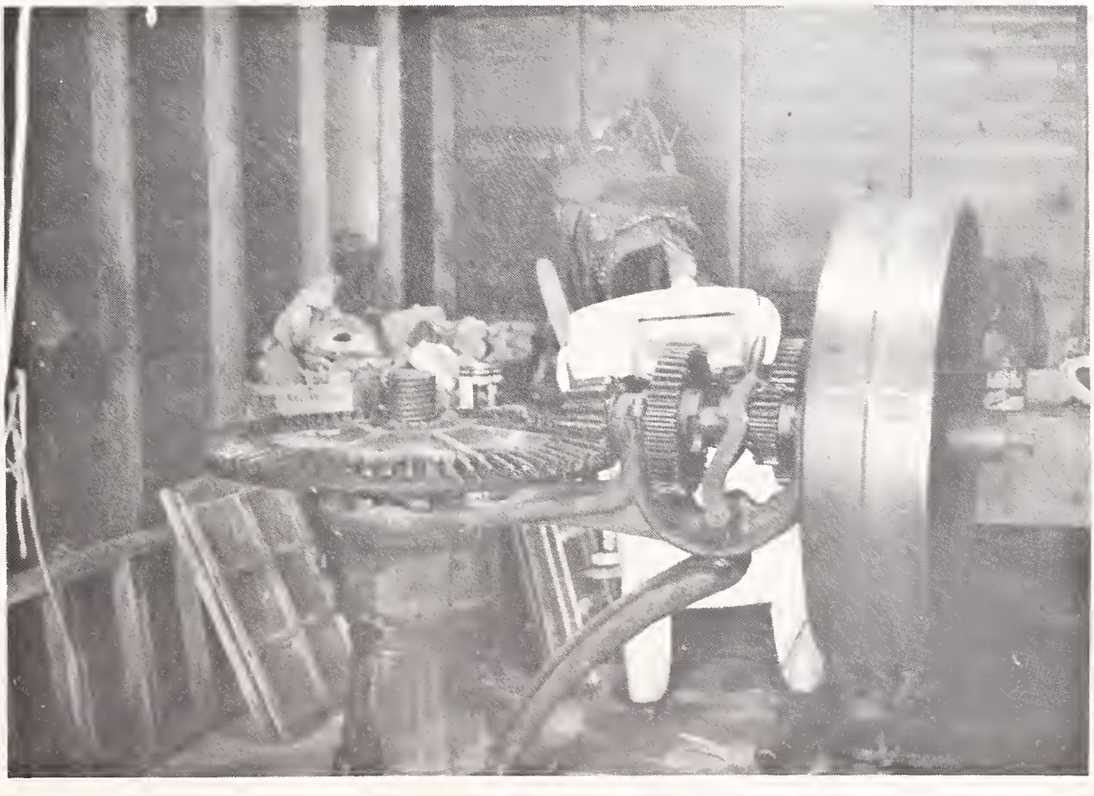


Photo 10 OPERATING CONTROL FOR LEFT TUNNEL

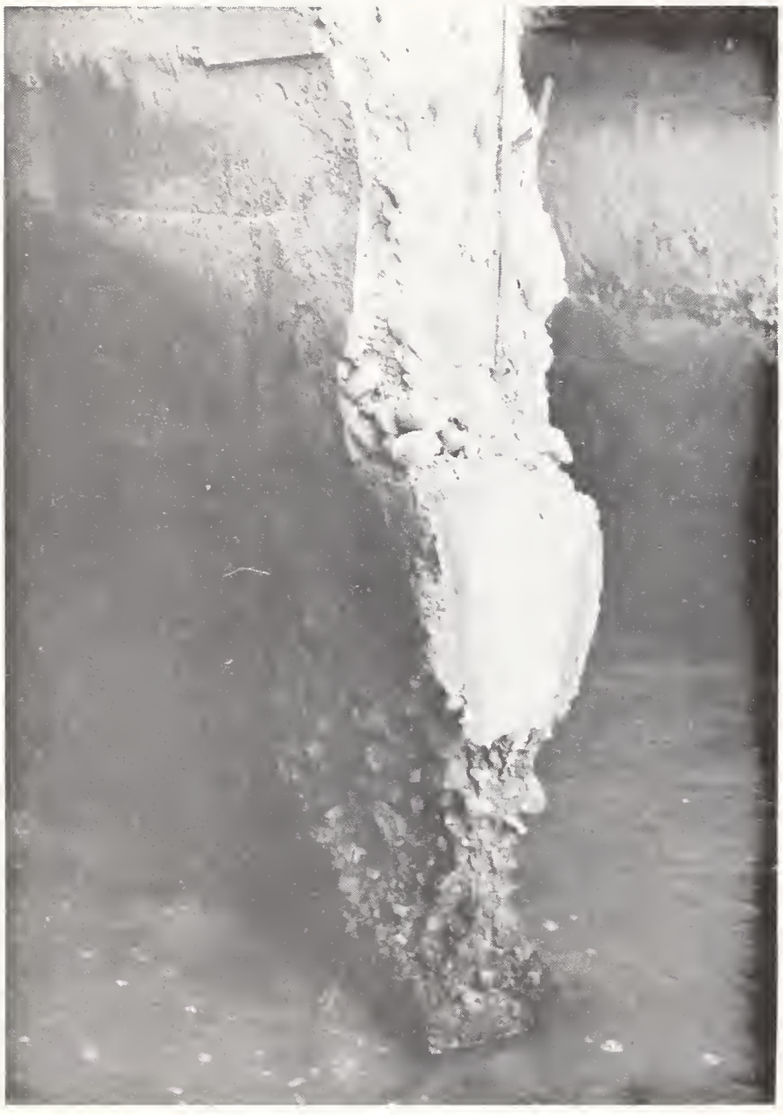


Photo 11 INTERMEDIATE WALL BETWEEN TUNNELS AT OUTLET STRUCTURE

Photo 12 DISPLACEMENT IN LEFT RETAINING WALL OF OUTLET STRUCTURE

Photo 13 OCTOBER 1978 — REPAIR OF INTERMEDIATE WALL AND OUTLET BASIN

Photo 14 OCTOBER 1978 — OUTLET BASIN DRAINED FOR REPAIR OF APRON

Photo 15 LEFT TUNNEL CEILING CAVITY

Photo 16 HOLE THROUGH INTERMEDIATE WALL NEAR END OF TUNNEL

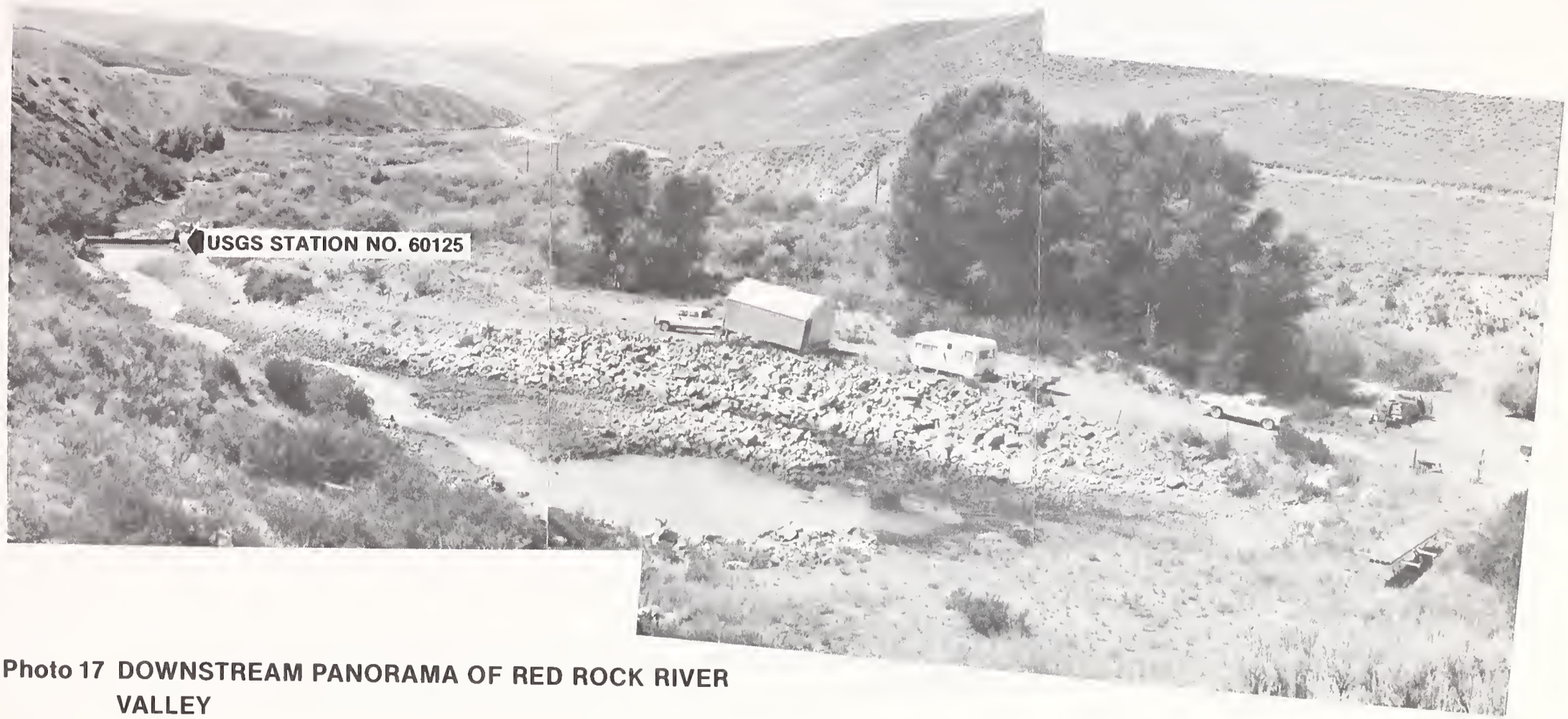


Photo 17 DOWNSTREAM PANORAMA OF RED ROCK RIVER VALLEY

Photo A FIRST LIMA DAM CONSTRUCTION AROUND 1890
PHOTO COURTESY OF BEAVERHEAD MUSEUM, DILLON, MONTANA

Photo B FIRST LIMA DAM
PHOTO COURTESY OF BEAVERHEAD MUSEUM, DILLON, MONTANA

Photo C SECOND LIMA DAM BUILT 1909
PHOTO COURTESY OF BEAVERHEAD MUSEUM, DILLON, MONTANA

CORRESPONDENCE

WATER USERS IRRIGATION COMPANY
RICHARD WIEBER, SECRETARY
OWNERS OF LIMA DAM AND RESERVOIR
P. O. BOX 1046
DILLON, MONTANA

October 22, 1979

Department of the Army
Seattle District Co.
Corps of Engineers
P.O. Box C3755
Seattle, Washington 98124

Attention: John A. Poteat

Re: Review of a Final Draft of a Phase I Inspection Report of Lima Dam, Situated in the Red Rock River Basin, Lima, Montana, Prepared by Seattle District U.S. Army Corps of Engineers (Designated MT-905) Under the National Dam Safety Program

Dear Mr. Poteat:

This letter is intended to constitute a reply to the Phase I inspection report of the National Dam Safety Program made with relation to the Lima Dam situated in the Red Rock River Basin. Such final draft was reviewed at a meeting of the stockholders of the Water Users Irrigation Company, a corporation (hereinafter referred to as WUIR). Such corporation is referred to in such report as the owner of the dam facility. The problems reported in such draft by the examining engineers were discussed by such membership and will be addressed in the body of this letter. In general, some stockholder members of the corporation who have lived the greater part of their lives in the vicinity of the dam, and who have a personal acquaintance with the history of weather conditions in the area, the Red Rock River Valley, and the operational use of the dam, find fault with the factual basis upon which the contractor engineering firm based its assumptions. These will be referred to in the following part of this letter. The officers of the corporation are authorized by the stockholders to take the actions required by such report in paragraphs 3.2 through 3.2.4 and by paragraph 3.2.7.

As required in Paragraph 3.2.1 of the report, the Water Users Irrigation Company employed Louie Day, of Sheridan, Montana, a retired S.C.S. employee, who had worked in the immediate area of the Lima Dam for a period of in excess of ten years, to prepare an emergency warning plan for the purpose required in such paragraph of the final draft. The Department of Natural Resources of the State of Montana, acting for the Governor of the State of Montana, has approved the qualifications of Mr. Day to perform this phase of the recommended procedures and preparation of such emergency warning plan is in progress, and, when finalized, will be submitted to the Department of Natural Resources of the State of Montana, and is intended to be implemented in the spring of the year 1980.

Paragraph 3.2.3

The required "expedient protection" mentioned in such paragraph is in process of implementation.

Paragraph 3.2.4.

As required by such paragraph, the Lima Reservoir was drained during the fall of the year 1979, and on September 26, 1979, representatives of the Montana Department of Natural Resources, officers of WUIR, and others, inspected the entire outlet structure and foundation in detail, when the dam was completely drained and the gates were opened. They also otherwise inspected in detail, as required by such paragraph. In addition, the inlet tunnels were inspected and the operation of the two gates was tested. The inlet tunnels were each found to be in excellent condition with no deterioration in the concrete. All surfaces were regular and no areas required repair. One crack appeared in the concrete of the southerly tunnel at its exterior end (upstream end). This was thought to have been caused during the original construction of the dam in backfilling. No displacement whatsoever was indicated and no repair of such crack was deemed necessary or required. The outlet gates were each found to work well. On particular inspection of each gate and its designed method of operation, the same were found to be in tact, in excellent condition, and each

worked as designed. No "binding" of the gate as anticipated in such report was found or experienced. No deterioration in any part of the gate structure could be observed of ascertained. The outlet tunnels were found to be as indicated in the final draft.

Paragraph 3.2.6

Reference is made to this paragraph of the final draft of such report to determine the recommendations contained therein. In order to approach the requirements thereof, the stockholders of WUIR engaged the services of Northwest Testing Laboratory, Great Falls, Montana, to conduct indicated drilling tests of the dam, and of its base, and to make a full written report of the findings thereof; and to make recommendations with relation thereto. Piezometers are to be installed and to be monitored during the course of such testing so arranged for. At such time as a full report has been received from the Northwest Testing Laboratory, the stockholder membership of WUIR is to meet again in order to then determine just what future actions the corporation owner will take with reference to the further implementation of the recommendations contained in the report.

Paragraph 3.2.7

The preparation and implementation of the recommended written operation and maintenance plan is intended following the investigative actions to be taken by the Northwest Testing Laboratory.

CONCLUSION

Those actions required to be done by the final report have been addressed by the stockholders of WUIR. The dam was drained and inspected as indicated and required. Testing has been arranged for with relation to the seismic considerations mentioned in the final report, and upon receipt of the results and the analysis of the seismic testing being done, and the installation and monitoring of the piezometers, and

the receipt of recommendations with relation to the findings made to appear in such report, the membership will then proceed with the further requirements of the final draft. (It should be readily apparent that the final conclusions with relation to what ultimately will have to be done with the dam will be, to a large extent, determined by the results of the testing, which is now ongoing).

COMMENT

It should be here reported that the membership (stockholders) of the WUIR have serious reservations as to some factual assumptions made by the examining engineers in the preparation of the final draft. Many of the stockholders attendant at that meeting have lived their entire lives in the Red Rock River Basin, and some of them, and their families, have lived in that vicinity with a day to day personal knowledge of the climatic and geographical situations which have existed in such valley over a period of many years. Such disagreements may be summarized as follows:

In the final draft the engineers assume that the PMF can be anticipated to occur in the months of May and June, and that all of the soils of the Centennial Valley will be frozen at the time of such occurrence. The engineers further state that because the whole of the valley will be, during that time, in a frozen condition, the soils are incapable of absorption of any rainfall, snow runoff, or other moisture producing condition occurring. Stockholders at their meeting alluded to the above and have stated that during the months of May and June in all of the years that such persons have actually lived in such area they, as resident livestock producers, have grazed cattle and other livestock on green grass growing in such area; that they have excavated soils, dug post holes, driven fenceposts, and made other excavations in the area without encountering any frozen ground whatsoever. It was stated that possibly, in some years for the first few days, or the first week of May, some of the soils in the floor of the valley may have a minimal frost content, but such condition is exceptional, and there was no year within the memories of any of the stockholders there present who

expressed themselves about which it could be fairly stated that the soil in the Centennial Valley would have been incapable of retaining the major part of any extremely heavy rainfall occurring during the months of May and June of any year. The stockholders also stated that snow cover in the high mountains tended to prevent the freezing of soils covered by such snow, and that such soils customarily retained a high proportion of the snow melt during runoffs each year. Such stockholders could not understand an assumption by examining engineers who would state that no part of a PMF occurring in the months of May and June in the Centennial Valley (Upper Red Rock River Basin area) would be absorbed by the soils.

The membership is advised, and understands, that there is a fall of about ten feet in the fifty mile (approximately) length of the valley floor (measured from the top of the spillway at the western end of the valley, to a point approximately 50 miles easterly to the head of the Centennial Valley, and that, were an inundation to occur during the months of May or June as contemplated by the engineers preparing the final draft, large quantities of moisture would have been absorbed by the soils of the valley prior to the time that the crest of any flood would develop at the dam site, and that a possibility existed that the water of a PMF could be more readily retained in the Centennial Valley through an enlargement of the dam, than to enlarge the spillway or discharge capabilities of the existing dam so as to dump such PMF into the narrow valley below to ravage such valley, take out the Clark Canyon Dam and the City of Dillon downstream.

FUTURE ACTIONS INTENDED

The Water Users Irrigation Company intends, following its receipt of the report relating to the ongoing tests now being conducted at the dam site, to address itself to the remaining portions of the report contained in the final draft and the requirements which are set forth therein.

What the actions of the owner will be in connection with such matters will be determined to a large degree by the reports which will be received.

Copies of such reports, when received, will be forwarded. Further actions of the Water Users Irrigation Company with regard to the final draft, its conclusions and its requirements, will be determined by the corporation following the receipt of the reports on the testing.

Should you require further actions at this time (pending the receipt of the reports of the ongoing testing program) please advise.

Very truly yours,

WATER USERS IRRIGATION COMPANY

BY: _____

cc: Department of Natural Resources
W.G. Gilbert, Jr.

DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
WATER RESOURCES DIVISION

32 SOUTH EWING
HELENA, MT 59601

STATE OF MONTANA

THOMAS L. JUDGE, GOVERNO
TED J. DONEY, DIRECTO

November 26, 1979

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on Lima Dam. We feel the report is complete and satisfies the guidelines for the Phase I evaluation as outlined by the Office of the Chief of Engineers, Department of the Army.

The Department has been in contact with the Water Users Irrigation Company (WUIC), owners of Lima Dam. They are committed to the program and are progressing at a reasonable schedule with the recommendations defined in the final draft report.

Thank you for this opportunity to review and comment on the final draft report for Lima Dam.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
Water Resources Division
(406) 449-2864

RB/GM/rm

DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX C-3755
SEATTLE, WASHINGTON 98124

NPSEN-FM

22 January 1980

Richard Wieber, Secretary
Water Users Irrigation Company
P.O. Box 1046
Dillon, Montana 59725

Dear Mr. Wieber:

We appreciate your comments on the final draft Lima Dam report.

With regard to your comment on the assumed frozen ground condition, an extract from the "Summary of Soil Moisture Measurements For Montana" (Inclosure 1) is provided for your information. In this case the recording station is in the vicinity of Lakeview, Montana at elevation 6700, the approximate elevation of the Lima Project. During the period 1962 through 1978, the record indicates that frozen ground conditions did occur several times during the April-May time period. As stated in the report, the Probable Maximum Flood results from the most severe combination of critical meteorologic and hydrologic conditions reasonably possible in the watershed. Therefore, the measurements indicate that it is reasonable to assume a frozen ground condition. The final report will be changed to reflect selection of a April-May storm rather than a May-June storm.

We apologize for the delay in responding to your comments.

Sincerely,

SIDNEY KNUTSON, P.E.
Asst. Chief, Engineering Division

1 Incl
As stated

MORRISON-MAIERLE INC
QUALITY ASSURANCE

Roger C Foster
Project Manager

Thomas M. Walton
Branch Manager or Department Head

N-A
Peer Reviewer

Harold L Ellis Co
Principal-In-Charge

Chief Engineer No	Date Approved
80-17	6-

Project No. 1447-06-02